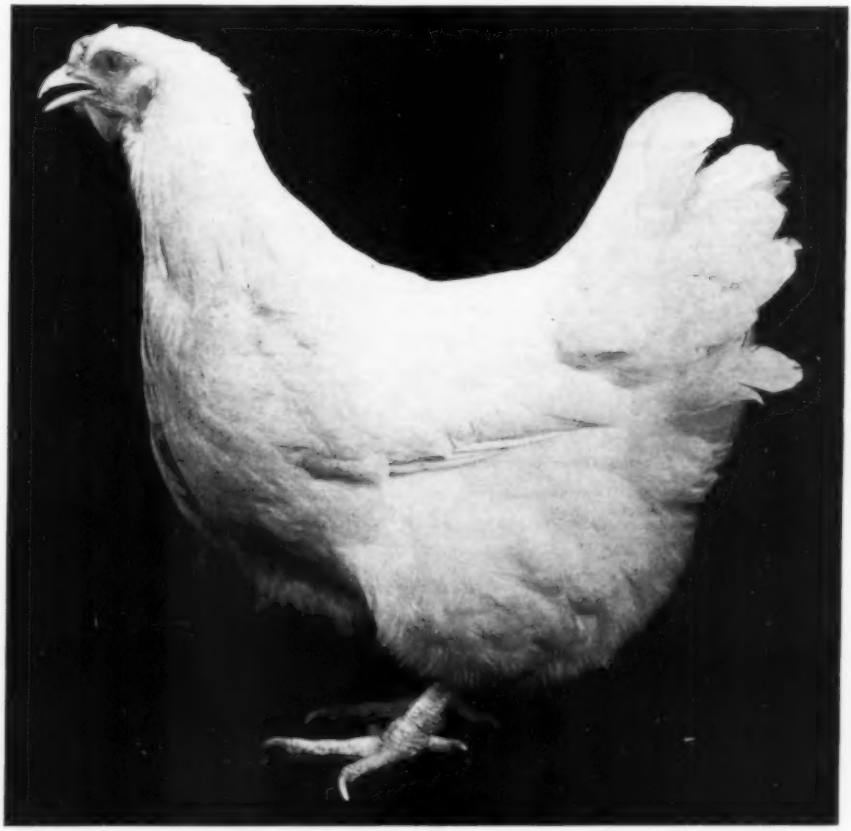
The Journal of HEREDITY



AN ALBINO HEN

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Twin Finger Prints
Inheritance of Albinism
Strawberry Breeding
Teratology in Eucalyptus
Stuttering and Handedness

VOLUME 24 OCTOBER, 1933 NUMBER 10

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An incorporated organization devoted to promoting a knowledge of the laws of heredity and their application to the improvement of plants, animals, and human racial stocks

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A CHIMERAL DELPHINIUM DUE TO GENE INSTABILITY

Frontispiece

The gene which controls color-development in the lavender delphinium is unstable and occasionally mutates to purple. This is the explanation of the variegated flowers produced by certain strains of the delphinium. In the plant shown above a change in the lavender-gene at a very early stage in development has resulted in a flower-spike that is half purple and half lavender. We have learned what is known about the genes by studying their variations, and the ever-sporting genes of the delphinium are especially well adapted to certain phases of these studies.

WHAT IS A GENE?

M. DEMEREC

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UNTIL a few years ago when the effect of x-rays on genes was discovered by Miller[16], the methods available to geneticists for direct studies of gene properties were highly unsatisfactory. High stability of the great majority of genes and inability to produce changes experimentally on any of the known genes made direct approach to the study of the gene a very difficult if not an impossible problem. A relatively small group of the so-called unstable genes was, before the x-ray discoveries, and probably still is, one of the best media for study of gene properties. However, a limitation is imposed on the usefulness of this material, by reason of the fact that even the frequent changes occurring naturally in these genes cannot be controlled experimentally. Muller's discovery that x-rays can induce changes in genes opened up a wide field of new possibilities. The work in this field, however, as far as gene properties are concerned, is in its infancy. The results are still small although the potentialities are great.

Our present information about genes is largely obtained by indirect, genetic methods. By studying the transmission of hereditary characteristics from one generation to another, genes were established as the mechanism instrumental in effecting this transmission; by following the inheritance of groups of characters, genes were placed in chromosomes and their location determined in respect to one another; by investigating different combinations of characters, evidence was obtained on the interaction of genes. The results of these indirect studies form the basis of our present gene concept. Studies of the effect of x-ray radiation and of unstable genes are the best means now available for broadening this concept.

Were we to attempt to define the term "gene," we could state that it is a minute organic particle, capable of reproduction, located in a chromosome and responsible for the transmission of a hereditary characteristic. This definition includes only statements of fact for which there is sufficient experimental evidence to prove them beyond reasonable doubt. In this presentation we shall endeavor to analyze the above definition, to discuss several directions in which this definition could be extended, and to present the concept of the gene which is used as our working hypothesis.

Gene Definition Analyzed

Size of the gene—Estimates of the size of the gene of *Drosophila melanogaster* were made by several investigators using two different methods. Morgan,[14] Muller,[17] and Gowen and Gay,[12] determined the volume of the chromosomes, estimated the number of genes present in the chromosomes, and, by dividing the volume by the number of genes, obtained an estimate of the average volume of a gene. Blackwood[1, 2] estimated the diameter of a gene from a comparison of the total number of gene changes with the number of ions produced by a given x-ray dosage.

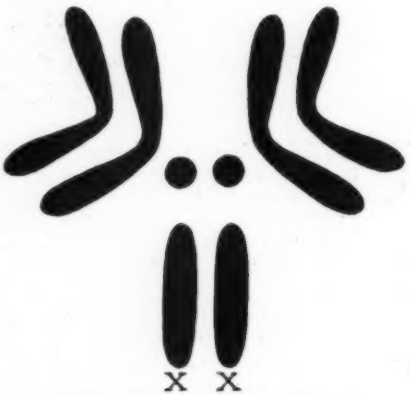
The three estimates made by Morgan gave the gene diameter as 20, 60, and 70 milimicrons; Muller's estimate gave about 50 milimicrons; Blackwood's 20; and Gowen-Gay's, about 10 milimicrons. All these estimates give the upper limit for the size of a gene.

*From the lecture series on Studies in Heredity given at the Carnegie Institution of Washington, in March 1933.

There is also a little direct evidence indicating that the gene is an ultramicroscopic particle. Professor A. F. Huettner* (unpublished material) found the following condition in early cleavage divisions of *Drosophila melanogaster* eggs when these were stained with Fulgen stain, effective only on chromatin. The resting nucleus is entirely clear. When the nucleus prepares itself for division, minute chromatin granules appear which increase in size and number, soon making the thread-like structure of long chromosomes evident. It is of interest in this case that in a definite position in the central region of the nucleus two small chromatin dots invariably appear which later develop into two small chromosomes and that the other granules are grouped in three sectors where, later, three large pairs of chromosomes appear. This indicates that gene strings of chromosomes have a definite position inside of a nucleus but that they are visible only when enough of the chromatin matrix has been evolved by them to increase their size to the point of visibility. The unavoidable conclusion from this finding is that the individual genes constituting the gene strings are ultramicroscopic.

The results of the work with x-rays indicate that the action of x-rays is direct, viz. that the change in the gene is the result of a hit by a photoelectron. The estimates just discussed put the maximum size of the gene within the range of the size of several large organic molecules. The effects observed in the x-ray work are more easily explained if a gene is pictured as a single organic molecule rather than as a small group of molecules. There is no evidence against the single molecule gene assumption.

Capacity of reproduction—Since every cell of an organism contains a full complement of genes, each gene must divide at every cell division. This self-propagating property of the gene is one of its important characteristics.



CARRIERS OF THE GENES

Figure 1

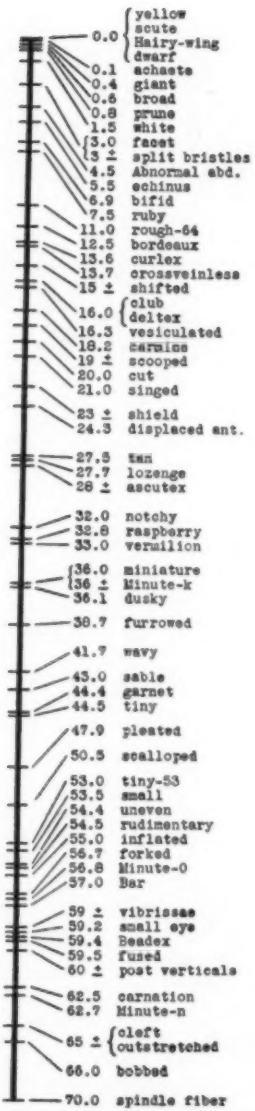
The four pairs of chromosomes of the fruit-fly have been more intensively studied than those of any other species. The genes are arranged in a definite order in the chromosomes, and by genetic analysis the relative positions of over two hundred genes have been determined in Drosophila. The "map" of one of these chromosomes, the *X* or sex-chromosome, is shown in Figure 2.

Little is known about the nature of gene reproduction. The evidence adduced by the author[9] from the study of unstable genes, however, indicates that the gene reproduces by formation of a new gene next to the old one rather than by the division of the old gene. This type of reproduction would favor the supposition that a gene is a single molecule.

Location of genes—A great mass of genetic and cytological evidence is now available to show that genes are located in chromosomes. The same evidence indicates that genes are arranged in a linear order. Since the individual genes behave as independent units a gene-string can readily be compared to a string of beads, each bead of which is ultramicroscopic in size.

The genetic and cytological evidence shows that genes are arranged in a

*The author is greatly indebted to Professor A. F. Huettner for the permission to use this material.



A "CHROMOSOME-MAP"

Figure 2

This map shows the genes of Drosophila located in the X-chromosome, and arranged in the order in which genetic "charting" places them. The "yard stick" used in making these measurements is the relative frequency of crossing-over of the various genes.

definite order and that they retain this order with great regularity. Each gene has its permanent *locus* on a gene string. The order of genes may be changed by various influences but these changes are an abnormal rather than a regular occurrence.

Figure 1 shows the chromosome group of *Drosophila melanogaster* and Figure 2 the genetic map of the *X*-chromosome. Distances between the loci of this map were determined by genetic methods. Cytological studies of Dobzhansky[10] and Muller and Painter[18] indicate that genetical distances between loci do not always correspond with the actual distances as they exist in chromosomes.

By changing its constitution a gene may attain several forms. Different forms of the same gene are called *allelomorphs*. Certain genes have a larger known number of different distinguishable gene forms than certain other genes. For example, for the gene located in the white locus of *Drosophila melanogaster*, at least eleven different allelomorphs are known, all of which affect the color of the eyes.

Transmission of hereditary characteristics—This property of the genes is the one through which the existence of genes was discovered. The study of the mode of transmission of hereditary characteristics gave the basis for the postulate that there exist mechanical particles responsible for this transmission. These particles were named genes.

We know today, however, that no single gene has the sole responsibility for the appearance of any one character. The final effect is produced through the interaction of the whole complement of genes, although certain genes may have a greater influence on the expression of certain characteristics than some other genes have.

Stability of the Gene

What produces natural changes in genes is not known, but we know that these changes, called mutations, occur in nature continuously at a very low

rate. X-rays and radium radiation increase the rate of mutations.

The experimental evidence shows that mutations occur with different frequency in different genes. The data of Stadler[23] on the frequency of mutations in seven genes of maize are a good illustration of this fact. (Table I). While gene *R* changed with frequencies of 492 times per million gametes, gene *Sh* changed with a frequency of 1.2, and, in the case of the gene *Wx*, no change was observed among more than one and one half million gametes. From the data of Morgan, Bridges, and Sturtevant[15] on recurrent mutations found in *Drosophila melanogaster* it may be inferred that a condition similar to that observed in maize exists also in *Drosophila*.

In the group of so-called "unstable genes" changes occur with a rather high frequency. There is, however, no sharp division between the stable and unstable genes. Using the rate of change as a criterion, genes can be arranged in a continuous series in which the highly stable forms constitute one extreme and the highly unstable forms the other extreme. It is known, furthermore, that the rate of change in various genes may differ in different tissues or at different stages of the development of the organism. In case of *Delphinium ajacis*, for example, two unstable genes affecting the color of the flowers are known, viz. the unstable rose and the unstable lavender (Fig. 3 and Frontispiece). Both of these genes change to purple.

Purple spots on flowers, therefore, mark the cells which originated from the cell in which the change in the gene had occurred. The number of spots indicates the number of changes, and the size of the spots indicates the stage of the ontogeny when the change occurred. It was evident from Figure 3 that lavender flowers have small spots only, while rose flowers have spots varying in size from small up to large ones.

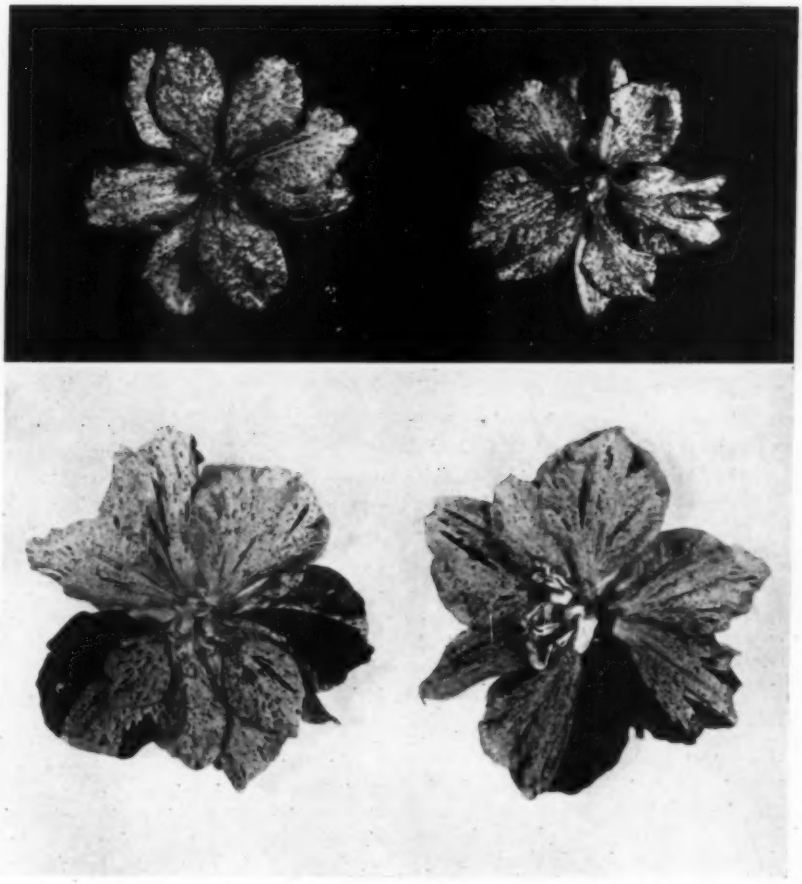
Since small spots represent late changes and large spots early changes, the size of the spots indicates that the lavender gene is unstable only late in the development of the flower and that the rose gene is unstable during all the developmental stages of the flower. Moreover, plants with large purple sectors (Frontispiece), representing early embryonic changes, are frequent in the lavender line but they are rare in the rose line. The lavender gene, therefore, changes with a high frequency early and late in the ontogeny and is constant or changes with a low frequency at other stages. The observations indicate that the rose gene changes at a uniform rate throughout the whole life cycle.

In *Drosophila virilis*, also, unstable genes are known which change at a different rate at different stages of ontogeny. Reddish-1-alpha, for example, is unstable at the maturation division of heterozygous females only; miniature-3-alpha is unstable in somatic cells and in germinal tissues and miniature-3-gamma is unstable in somatic cells only. All these genes possess a high degree of stability at all other stages of ontogeny.

Changes occurring in the somatic cells are much easier to detect than changes occurring in the germ cells, since it is much simpler to observe a large number of somatic cells than to observe a large number of germ cells. Of the two genes, therefore, both changing at the same rate, one which changes in somatic cells might be considered unstable while the other one, changing in germ cells only, might

Table I.—Stadler's data on the frequency of changes in seven genes of maize

Gene	Gametes tested	Number of mutations	Average per one million gametes
R	554,786	273	492
I	265,391	28	106
Pr	647,102	7	11
Su	1,678,736	4	2.4
Y	1,745,280	4	2.2
Sh	2,469,285	3	1.2
Wx	1,503,744	0	0



TWO TYPES OF GENE-CHANGES

Figure 3

Above are shown two flowers of the lavender strain. Each spot is formed by the mutation from lavender to purple of a single cell. The spots are all approximately the same size, showing that the change in the color-gene occurs only at a definite stage in development. Below are shown two flowers of the rose strain. Here the spots vary from tiny dots to half a petal in extent. It is evident that in this strain the change from rose to purple occurs at any time during the development of the flower. The chimeral (half-and-half) petals represent a mutation that occurred when the petal was in a very early stage of development and each tiny dot a mutation which occurred when the development of the flower was nearly completed. (See page 372.)

be considered stable. A double flower of Delphinium, for example, has about two million epidermal cells on which color changes can be detected. A medium sized plant bears about one hundred flowers. Changes occurring in the epidermal cells of flowers at a rate as low as one in ten millions could readily be detected and a gene changing at such a rate would be considered unstable. A gene, however, changing with that rate in germ cells only, would

be considered to be highly stable. In such a case, therefore, not the rate of change but the tissues in which this change occurs would be used as a criterion of stability. The *R, I, Pr, Sn, Y,* and *Sh* genes of maize, investigated by Stadler, would be considered unstable if they changed in somatic cells at the rate they change in germ cells, according to data of Table I.

It appears, therefore, that unstable genes differ from the stable ones only in the fact that they change with a relatively higher frequency and that, in the majority of cases, the change occurs in tissues where this change can be readily detected.

Nature of Gene Changes

The changes in genes cannot be observed directly. The only possible way of studying them is by studying the effect which the changed gene produces in a character. It has been found that a change in a gene at a certain locus produces a certain effect. Change in the wild type gene of yellow locus of *Drosophila* produces a gene which makes the body color yellow, change in the wild type gene of the miniature locus produces a gene which makes wings miniature, in the forked locus a gene which makes bristles forked.

In a few loci, however, through different changes in the same gene several different genes may result, each producing a different though similar effect. As it has been mentioned before, eleven gene forms (allelomorphs) are known in the white locus, each form being responsible for a different eye color. These can be arranged in a series as follows: red, coral, blood, cherry, apricot, eosin, ivory, tinged, buff, ecru, and white.

Changes in genes occur in both directions, from the wild-type to the mutant type and in the reverse direction from the mutant-type to the wild-type. Changes from the wild-type to the mutant-type appear to be more frequent. The evidence is ample that under the influence of x-ray radiation these changes are much more frequent than the changes in the opposite direction.

In the case of unstable genes the mutant gene is the one which is usually unstable and in the majority of the known cases the change occurs from the mutant to the wild-type with a higher frequency than the reverse change.

The rate of change in unstable genes is sufficiently high to be measured and therefore evidence is being accumulated from that source which can be used to make an inference as to the nature of the gene changes. This evidence suggests that changes in genes are chemical processes. It may be summarized as follows:

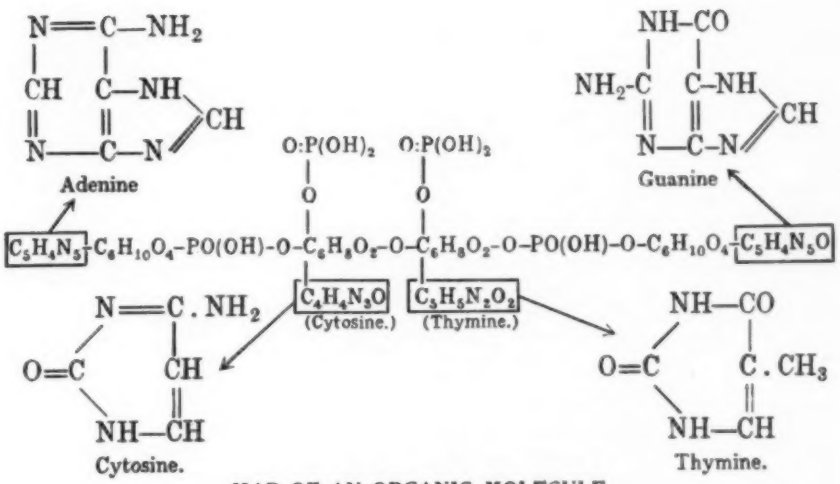
(1) The end product of the change is always the same. There are no intermediate forms. The unstable rose gene of *Delphinum* changes always into its wild type allelomorph, which is purple, and unstable lavender changes into its wild-type allelomorph which is also purple. The same condition exists in unstable genes of *Drosophila virilis* (Demerec)[4,5,6] maize (Emerson),[11] Portulaca (Blakeslee),[3] Pharbitis (Imai),[13] and of other plants.

(2) The change is not always a random process; it may be favored by certain tissues or even it may be limited to certain tissues, as shown in the previous discussion. In order that the change may take place a certain environment is apparently required and this requirement is fulfilled in certain tissues.

(3) Several genetic factors are known to stimulate the rate of change

TABLE II.—Influence of Modifying Factors on the Rate of Change of the Unstable Miniature-3 Alpha Gene of *Drosophila virilis*.

Modifying factor	Rate of change of miniature-3 alpha in	
	Soma	Germinal tissues
none	low	low
S-1, s-2, S-3, S-4	high	low
M	low	high
M and S-1, s-2, S-3, S-4	high	high



MAP OF AN ORGANIC MOLECULE

Figure 4

Above is shown the tentative structure of thymus nucleic acid. The generalized formula is given in the center and simply shows the chemical constitution of the various groups. These each have a definite and complicated structure, as is shown in the detailed "maps" of four of the groups, adenine, guanine, cytosine and thymine. These groups also occur as separate molecules. The detailed map of the entire molecule would be an extremely complicated affair. This sketch is a sample of an extremely complex organic molecule which may serve as a crude diagrammatic picture of what the structure of the gene molecule may look like. Any variation in the constitution of any of the groups that make up such a molecule may have profound effects on the properties of the entire complex. Changes in one or more of the atoms making up gene molecules can be pictured as the basis of the mutations which, at varying rates, take place in many of the genes that have been studied in the laboratory.

in certain unstable genes. This situation is best analyzed in case of the unstable miniature-3 gene of *Drosophila virilis* (Demerec)[7,8] and is partially summarized in Table II. From this table it can be seen that factors *S-1, s-2, S-3,* and *S-4* increase the rate of change in somatic cells and that factor *M* increases that rate in the germinal tissues. These factors, apparently, produce environmental conditions which favor the occurrence of the change.

The results of x-ray experiments, especially the discovery that changes produced in genes are reversible and that the x-rays produce the changes directly, favor the conception that changes in genes are chemical changes.

A Working Hypothesis

It should be made clear that the present knowledge of the gene is inadequate for the formulation of a definite hypothesis about the nature of the gene. Any concept of the gene has to be temporary, and designed primarily not for the purpose of explaining the data now available but for use in planning experiments to test the validity of various assumptions. Assumptions which cannot be tested, or which are not being tested, have the tendency to hinder rather than to facilitate progress.

The gene concept as presented here is the working hypothesis we are using in our investigations. The essential points of this hypothesis are either

being tested by experiments now in progress or will be tested as soon as the physical facilities of our laboratory will permit.

Physical Picture of a Gene

The experimental evidence indicates that genes are not larger than a particle containing a few complex organic molecules. This same evidence suggests that genes are probably uni-molecular structures.

In developing our working hypothesis, we shall assume, therefore, that genes are single, complex organic molecules. This assumption appears to be the more probable of the two and it is also the simpler of the two to use.

The assumption of the uni-molecular structure of the gene, however, is not the essential part of our hypothesis. Only a few insignificant changes would be required in the hypothesis to adapt it to the multi-molecular gene concept.

If a gene is a complex organic molecule it would be expected to be similar in composition to other complex molecules, viz. molecular groups constituting this molecule (whatever these groups may be) would be arranged in chains and side chains. Figure 4 may serve as a crude diagrammatic example of what the structure of the gene molecule may look like.

The diagram is not intended to give any implication as to the number, the type, or the arangement of the molecules in a gene group. Its purpose is to illustrate the molecular structure of a complex organic molecule.

Allelomorphs

It has been mentioned before that through different changes in the same gene several different genes (allelomorphs) may be formed.

The allelomorphs of the miniature locus of *Drosophila virilis* may be arranged into a two-dimentional series as follows:

mt-1 ➤ mt-3 ▼ beta ➤ mt-2 ➤ mt-5 ▼ beta ➤ mt-4
mt-3 ▼ gamma mt-5 alpha
mt-3 alpha

In the horizontal line, allelomorphs are arranged according to the size of the wings and in the vertical line according to the degree of stability (mt-3 and mt-5 allelomorphs being unstable). There is a much closer connection between the allelomorphs of the two vertical groups than between the allelomorphs of the horizontal group, since a transformation of one allelomorph into another in the vertical groups occurs rather frequently and this transformation has never been observed for the allelomorphs of the horizontal group. This evidence suggests that changes producing different allelomorphs are independent of each other and indicates that they might arise by changes in different groups of a gene molecule.

There is a possibility to test this concept and experiments planned for this purpose are now under way. The procedure is as follows: white locus of *Drosophila melanogaster* has about eleven allelomorphs, four of which are red, erosin, apricot, and white. White can be obtained by a change from red as well as from eosin and apricot. Now, if it is true that by a change in a certain molecular group an eosin gene is produced, by an independent change in another group apricot is produced and that a change in still another group gives white, then whites obtained from red, eosin, and apricot should be different from each other in that a reversion from white obtained from red should give red, a reversion from white procured from eosin should give eosin, and that coming from apricot should give apricot as indicated below:

red	➤	white	➤	red
eosin	➤	white	➤	eosin
apricot	➤	white	➤	apricot

One fact in support of this contention is available in the results obtained by Timofeeff-Ressovsky.[24] By use of x-rays he produced several reversions in the white gene. In the only case in which the origin of the treated white was mentioned the white originated from eosin and reverted back into eosin. This process may be outlined as follows: eosin—>white—>eosin.

The Nature of Gene Changes

Where there are several allelomorphs known in the same locus they usually affect the same character, differing only slightly in the degree of their effect. This suggests that slight changes in the gene molecule are responsible for the occurrence of different allelomorphs.

If we examine changes produced by x-rays in different loci of *Drosophila melanogaster* (Patterson[20]) it will be noted that out of 24 tested changes in the white locus, 20 were lethal and 4 were visible; out of 18 changes in the yellow locus, 16 were lethal and 2 visible; and out of 17 changes in the miniature locus, 15 were lethal and 2 were visible. It is evident from these data that only 14 per cent of changes observed in these loci gave allelomorphs which produced a visible effect and 86 per cent of changes acted as lethals, viz. eliminated all homozygous flies.

The question now arises: what are these lethals? The answer to that question is suggested in the results of work on deficiencies by Bridges.[3] It has been found that the absence or inactivation of a small region of a chromosome acts as a lethal similar to lethals observed in the loci mentioned above. This would indicate that either the observed lethals are due to deficiencies of a region of the chromosome or that they are eliminations (deficiencies) of a single gene. The second assumption seems more probable.

How a gene can be eliminated? The process of elimination could be conceived either as a direct destruction of the gene or as a loss of power of reproduction by the gene. The second process would be the simpler of the two and it may be expected to occur with a higher frequency.

According to this concept a gene molecule can stand but a very slight change. Any radical change eliminates the gene from the gene complex and the elimination of a single gene (with certain exceptions) has a lethal effect on the organism. This leads us to an important conclusion that a full complement of genes is required for the organism in order to live. The evidence is even available[19] which indicates that a cell without a full complement of genes cannot function properly. Experiments are now under way to obtain more data on this point.

If a whole complement of genes is necessary for an organism to live or even for a cell to function properly, the primary function of a gene is not the one by which we recognize it, viz. the determination of a visible characteristic, but it is the regulation of the life processes of the cell. The effects which different genes exert on different visible characteristics of an organism are only incidental to their primary function. Furthermore, if one line possesses only a few loci not present in another line that fact would cause a high degree of sterility among the offspring produced by crossing these two lines. Even a difference in one locus of the type described by Patterson[21] as a "viability gene" would be sufficient to produce an almost complete incompatibility between two lines, one possessing the gene and the other not possessing it. Such a difference would be sufficient for the formation of a new species.

Evolutionary Progress Through Gene Changes

Since the change in any of the established loci is limited because any radical change in the gene is either lethal to the gene or lethal to the cell not adjusted to such a change, no great evolutionary progress could be expected through changes in genes which we now call mutations. Such progress could be expected through gene changes only if an extensive change occurs in the environment in which the species lives. In that case the change in the environment would require a new adjustment in the gene complex which may bring out as a most suitable form (wild type) a form different from the one which was most suitable in the original environment.

Evolutionary progress may take place through additions of new loci to a gene complex. It would require time, however, for a new locus to become established as an integral part of the gene complex, but once that is accomplished such a change would go a long way toward formation of a new species. It seems possible that the bar locus of *Drosophila* may be such a new locus which has not yet become established in the gene complex of that species. Experiments are now under way which may give an answer to this question.

Conclusion

This presentation may be concluded by summarizing briefly our present conception of the gene. We visualize genes as single organic molecules. The gene string, then, gives us an interesting picture of a group of molecules held together by some unknown force in a string, each molecule possessing a power of self propagation, and each one individually and all of them together having an almost magic power of governing life processes of cells in which they are located, and therefore of governing life processes of the organism of which these cells are an integral part.

Literature Cited

1. Blackwood, O., 1931. X-ray evidence as to the size of a gene. *Phys. Rev.*, 37: 1698.
2. ————, 1932. Further x-ray evidence as to the size of a gene; and as to the energy of mutation by ultraviolet rays. *Phys. Rev.*, 40:1034.
3. Blakeslee, A. F., 1920. A dwarf mutation in Portulaca, showing vegetative reversions. *Genetics* 5:419-433.
4. Bridges, C. B., 1917. Deficiency. *Genetics*, 2:445-465.
5. Demerec, M., 1926. Miniature-alpha—a second frequently mutating character of *Drosophila virilis*. *Proc. Nat. Acad. Sci.*, Washington, 12:687-690.
6. ————, 1927. Magenta-alpha — a third frequently mutating character in *Drosophila virilis*. *Proc. Nat. Acad. Sci.*, Washington, 13:249-253.
7. ————, 1928. Mutable characters of *Drosophila virilis*. I. Reddish-alpha body character. *Genetics*, 13:359-388.
8. ————, 1929. Genetic factors stimulating mutability of the miniature-gamma wing character of *Drosophila virilis*. *Proc. Nat. Acad. Sci.*, Washington, 15:834-838.
9. ————, 1930. A genetic factor affecting germinal mutability of minature-alpha wing character of *Drosophila virilis*. In *The Laws of Life*, pp. 45-56, Prague.
10. ————, 1931. Behaviour of two mutable genes of *Delphinium ajacis*. *Jour. Genetics*, 24:179-193.
11. Dobzhansky, T., 1932. Cytological map of the x-chromosome of *Drosophila melanogaster*. *Biol. Zentralbl.*, 52:493-509.
12. Emerson, R. A., 1917. Genetical studies of variegated pericarp in maize. *Genetics*, 2:1-35.
13. Gowen, J. W., and Gay, E. H., 1933. Gene number, kind, and size in Drosophila. *Genetics*, 18:1-31.
14. Imai, Y., 1927. The vegetative and seminal variations observed in the Japanese morning glory, with special reference to its evolution under cultivation. *Jour. College of Agr.*, Imp. Univ. Tokyo, 9:223-274.
15. Morgan, T. H., 1922. Croonian lecture on the mechanism of heredity. *Proc. Royal Soc.* B, 94:162-197.
16. ————, Bridges, C. B., and Sturtevant, A. H., 1925. The genetics of Drosophila. *Bibliographia Gen.*, 2:1-262.
17. Muller, H. J., 1927. Artificial transmutation of the gene. *Science*, 66:84-87.
18. ————, 1929. The gene as the basis of life. *Proc. Internat. Congr. Plant Sci.*, 1:897-921.
19. ————, and Painter, T. S., 1932. The differentiation of the sex chromosomes of Drosophila into genetically active and inert regions. *Zeit. ind. Abst. Vererb.*, 62: 316-365.
20. Patterson, J. T., 1929. The production of mutations in somatic cells of *Drosophila melanogaster* by means of x-rays. *Jour. Exp. Zool.*, 53:327-372.
21. ————, 1932a. Lethal mutations and deficiencies produced in the x-chromosome of *Drosophila melanogaster* by x-radiation. *Am. Nat.*, 66:193-206.
22. ————, 1932b. A gene for viability in the x-chromosome of Drosophila. *Zeit. ind. Albst. Vererb.*, 60:125-136.
23. Stadler, L. J. Material published in abstract form in *Anat. Rec.*, 47:381, 1930, and in the *University of Missouri Bull.*, 300: 77, 1931. The material was also shown at exhibits of the Sixth International Congress of Genetics.
24. Timoffeeff-Ressovsky, N. W., 1930. Das Genovariieren in verschiedenen Richtungen bei *Drosophila melanogaster* unter dem Einfluss der Röntgenbestrahlung. *Naturwissenschaften*, 18:434-437.

INHERITANCE OF ALBINISM IN THE DOMESTIC FOWL

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FOR a period of years investigators have known three independently acting factors for white plumage in the domestic fowl. The dominant white factor which is characteristic of the White Leghorn breed is dominant or epistatic to all pigments except red which is not entirely masked when the white is in a heterozygous condition. There are also two recessive white factors which have been shown by Punnett[3] to be independent in their action. One, which is characteristic of the Silky White Bantam, appears to be limited to the bantam varieties. The cross of the Silky White to the White Dorking breed produced colored birds in the first generation indicating that each must carry the dominant allelomorph of the white carried by the other. The white of the Dorking breed seems to be due to the same factor which is responsible for the white color of the White Plymouth Rock and the White Wyandotte.

In 1928 the writer's attention was called to some pink-eyed chicks appearing in a White Wyandotte flock of the Ross Brothers' Hatchery, Junction City, Kansas. Although several such chicks were obtained only one, a male, was reared to sexual maturity the first year. The poor success in rearing these chicks seemed to be due to defective eyesight which handicapped them in finding their food.

Since the pink eye condition occurred in a White Wyandotte flock, the characteristics immediately suggested those of an albino. However, inasmuch as the variety in which the pink eyes appeared was normally white this could only be determined by outcrossing the pink-eyed male (1119M) to colored females known not to carry the factor for any recessive white. This was done and only colored-plumage, normal-eyed F_1 generation birds resulted. The F_1 generation females were then back crossed to their father, the pink-eyed White Wyandotte male, 1119M. As is shown in the accompanying table, 88 offspring were obtained from this mating, of which 38 showed white plumage and pink eyes; 4 white plumage, normal eyes; and 46 colored plumage, normal eyes. Thus, it is seen that pink eyes occurred only in the birds with white plumage. The association of these two characters can be explained by the existence of very close linkage between the two different factors or that the pink eye and white plumage are both due to the action of a single factor which causes the pigment to fail to develop in both the eye and the plumage. Since albinism is known to occur in many vertebrates it seems probable that the latter explanation is the correct one. The individuals having white plumage and normal eyes which were obtained in the back cross, would be expected due to the independent segregation of the recessive white factor carried by the White Wyandotte breed.

With independent segregation of the two factors for white, four genotypes in equal numbers would be expected Using the symbol *w* for the recessive white and *a* for albinism the genotypes would be; one heterozygous for each color factor (*WwAa*), one homozygous for the Wyandotte white (*wwAa*), one homozygous for the albino white (*Wwaa*), and one homozygous for both recessives (*wwaa*). Since the last two types could not be distinguished one from the other the expected phenotypic ratios would be one normal-eyed colored, to one normal-eyed white, to

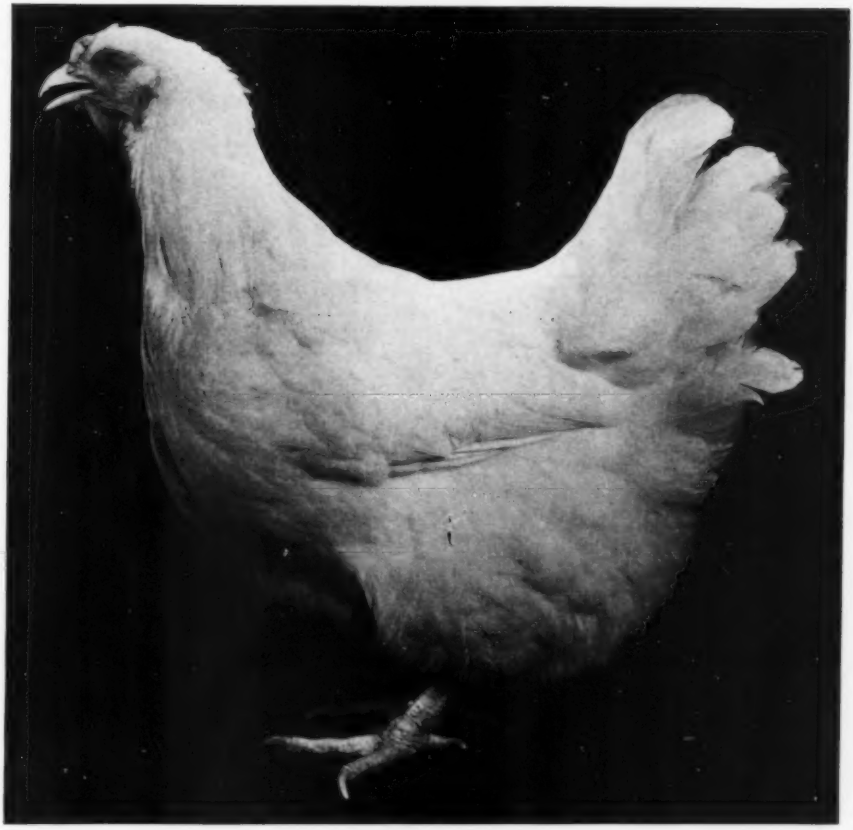
* Contribution No. 71 from the Department of Poultry Husbandry.

two pink-eyed whites. It is seen that there is a rather pronounced shortage of normal-eyed whites as well as of pink-eyed whites (albinos). Since half of the pink-eyed whites are also homozygous for the recessive white it would seem that some factor eliminating the recessive whites is responsible for the shortage in these two groups. These results are suggestive of the action of an autosomal lethal gene closely associated with the factor for the recessive white.

A second mating was made in which heterozygous females were back crossed to two other albino males. Some of the females used in the original back cross were here used together with several other F_1 generation females. These two males, 1193M and 1194M, came from the same White Wyandotte flock which produced 1119M. From the data shown in the accompanying table it is seen that the ratios obtained approach very closely the expected ones providing the factor for albinism is a simple recessive, segregating independently of that for the Wyandotte recessive white. The ratios were 248 albinos to 139 normal-eyed whites to 124 normal-eyed colored individuals from a total of 511 offspring. There was some shortage of the albinos but the ratio approaches sufficiently closely that of 2 albinos: 1 normal-eyed white: 1 normal-eyed colored to indicate that the factors for recessive white and albinism segregate independently. The results do not exclude the possibility that the original albino male may have carried a lethal factor closely associated with the factor for recessive white. Since his own daughters were back crossed to him such a factor would have an opportunity to express itself. The difference between the two matings here reported may be that the two males used in the second mating did not carry the lethal factor. Although all three albino males used came from the same flock of White Wyandottes, their genetic constitution might differ since a lethal factor eliminates the bird carrying it in a homozy-

TABLE I. Results of Albino Crosses.

	Male 1119M								
	Daughters			Sons			Sex unknown		
Female No.	Colored plumage, normal eye	White plumage, normal eye	White plumage, pink eye	Colored plumage, normal eye	White plumage, normal eye	White plumage pink eye	Colored plumage normal eye	White plumage normal eye	White plumage, pink eye
5388A	5	1	2	6	1	2	2	1	--
5469A	1	--	2	--	--	--	--	--	--
5470A	10	--	5	4	--	7	--	--	2
5997A	5	--	3	2	--	4	--	--	--
5998A	7	1	10	4	--	1	--	--	--
Total	28	2	22	16	1	14	2	1	2
Grand Total	50 normal-eyed to 38 albinos								
	Males 1193M and 1194M								
5388A	8	8	8	8	8	6	--	1	1
5470A	4	5	5	2	2	9	--	--	2
5998A	4	2	7	1	1	--	--	--	--
6771A	3	2	1	3	3	3	--	--	--
6772A	7	10	16	7	11	13	--	--	4
6773A	11	12	16	8	7	13	--	1	4
6776A	8	7	13	3	6	12	--	1	2
6778A	1	3	11	4	4	10	1	1	1
6779A	2	5	8	--	7	7	--	--	--
6780A	--	--	--	1	--	--	--	--	--
6781A	5	4	5	3	--	4	--	--	--
6783A	1	2	--	1	--	4	--	--	--
6789A	2	3	8	6	2	11	--	--	5
6790A	9	7	16	7	12	17	--	--	--
6862A	4	2	3	2	5	4	--	--	--
Total	69	70	116	54	65	113	1	4	19
Grand Total	263 normal-eyed to 248 albinos								



AN ALBINO HEN

Figure 5

Three separate genes which produce white plumage in fowls have long been known. These are: (1) the dominant white of the Leghorn, (2) the recessive white of the Silky Bantam, and (3) the white, also recessive, of such breeds as the White Wyandotte and the White Plymouth Rock. All of these white breeds have normally pigmented eyes and skin so that they are not true albinos. The hen shown above owes her white color and pink eyes to a gene distinct from those described above. It appears to be analogous to true albinism as it is recognized in many species. The eyesight of these pink-eyed birds is so defective that their value to the practical poultryman is probably slight but they will undoubtedly prove valuable in further studies of the genetics of the hen.

gous condition, and many individuals of a flock would be without it.

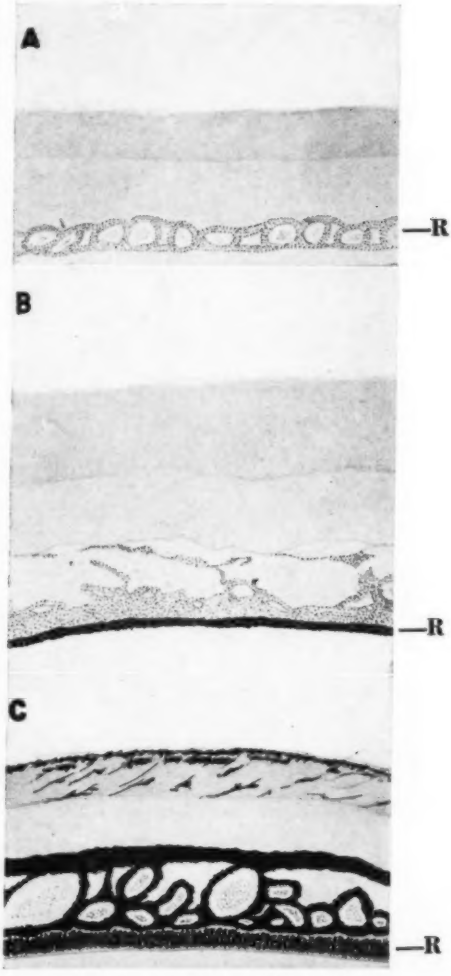
In connection with these results it it of interest to note that Dunn[1] also reported evidence for a lethal factor in this same variety of fowl. His results also indicate that the lethal was closely associated with that for recessive white. These results and those obtained by Dunn are of special interest since this variety of fowl is in somewhat ill repute for the hatching quality of its eggs.

Is This a True Albinism?

It is difficult to demonstrate that this new factor for white is true albinism. It might possibly be a case of

very close linkage between two new factors, recessive white and pink eye. However, out of 288 pink-eyed individuals produced, no instance was found where the pink eye segregated independently of white plumage. Albinism is well known in other vertebrates and this character shows other characterisics of albinism. Defective eye sight, which is frequently characteristic of albinos in other forms, is here evident. The chicks find difficulty in locating their food in early life and the birds show evidence of being unable to see well throughout life. Among the adults there is considerable variability in their ability to see sufficiently well to get about. Even though the entrance remains open, the albinos seldom leave the building in which they are housed. In the crosses used in this study albinism has been brought in on the male side since the females do not see well enough to make use of a trapnest when laying, which makes it impossible to carry through individual pedigrees. Also, since there is considerable difference in the impairment of the sight, the few males necessary may be chosen from among those showing the least handicap from albinism.

The albino chicks show a translucent red eye with no evidence of any pigmentation. The iris of most of the adult albinos shows some of the yellowish red color characteristic of the normal adult eye although in most cases it may be distinguished easily from the normal eye. This development of some pigment in the eye of the adult albino threw some doubt on the question of its being a true albino. In order to determine whether the albino eye was really different from the normal in the adult condition a histological study was made of the iris. In preparing the iris for histological study the standard technique was followed. The whole eye was fixed and a section of the iris was removed for cross sectioning. The fixation used was formol-acetic and staining was done with Delafield's haematoxylin and counterstaining with eosin. After fixa-



PIGMENT DISTRIBUTION IN EYE

Figure 6

Cross sections of the iris of the eye of the chicken showing the distribution of pigment in three types of eye color. *A*. Albino fowl eye, no black pigment. *B*. White Leghorn eye showing pigmented retina. This eye color is characteristic of most breeds of the fowl. *C*. Silky Bantam eye. A black eye with pigment showing in most of the tissues. R=Retina.

tion and before staining, the difference in pigmentation of the normal and the albino eye was clearly brought out. The normal eye showed considerable pigment while the albino eye was very transparent.

In Figure 6 the pigmentation of the iris of the albino eye may be compared with that of the normal eye of the White Leghorn and the black eye of a Silky Bantam. In the White Leghorn eye the melanin pigment is limited to the retina while in the Silky fowl it is distributed very generally through the tissues of the eye. In the albino there was no evidence of pigment anywhere. This would support the other evidence that this is probably a true case of albinism.

Another interesting consideration is that of the presence of xanthophyll pigment in these albino fowls. Albinism is generally held to prevent the development of all pigment. In these studies it has been found that the albino may have either white or yellow skin. The portion of the body where the factor for yellow skin may be most easily recognized is the legs. If the albinos carried the factor for yellow skin, they had yellow legs. They also were able to deposite xanthophyll in the yolk of their eggs. It would then appear that albinism does not prevent the appearance of the pigment xanthophyll in the tissues. Consideration of the fact that xanthophyll is not on the same physiological basis as is other pigment, permits explanation of its presence in albinos. Other pigments are manufactured in the body of the animal while xanthophyll pigment is taken unchanged from the plant tissues into the animal tissues. Palmer and Kennedy[2] reported that they "were unable to find any pigment soluble in alcohol or petroleum ether in the suprarenals of the albino rat." They also state that pigmentation of this organ was variable in other normal members of the mammalian group so that its absence in the albino rat is not necessarily due to albinism.

It seems that we have here a new recessive factor in the fowl which has the characteristics of an albino. This adds a fourth member to the series of whites in the domestic fowl. The factor is clearly expressed in the day-old chick since the brilliant pink eye readily distinguishes the albino from the normal which has black eyes at hatching. The expression of the factor at hatching makes it of value for further genetic studies. However, the poor viability of the albino due to poor eyesight rather seriously interferes with the general use of the factor. In order to rear the albinos successfully special protection must be given them against unfavorable environmental conditions and they should not be placed in competition with normals.

Literature Cited

1. Dunn, L. C. 1923. A lethal gene in fowls. *Amer. Nat.* 57: 345-349.

2. Palmer, Leroy S. and Cornelia Kennedy 1921. The relation of plant carotinoids to growth and reproduction of albino rats. *Jour. Biol. Chem.* 46: 559-577.

3. Punnett, R. C. 1923. *Heredity in Poultry.* London. Macmillan and Co. 204 p.

Science Through the Centuries

INTRODUCTION TO THE HISTORY OF SCIENCE, *by* George Sarton. Volume II, Parts I and II. 1251 pages. Price, $12.00. Carnegie Institution of Washington Publication No. 376. Williams & Wilkins, Baltimore. 1931.

A VAST storehouse of information regarding the slow and difficult progress of science through the Dark Ages is opened in the second "volume"* of George Sarton's *Introduction to the History of Science.*

Only recently has science entertained the ideal of becoming altogether "pure," and ostentatiously of "no conceivable practical value."

* The quotation marks are used advisedly. The 1251 pages of "volume II" are bound in two separate "parts," each of which would make two books of more than average size.

Those who are thus wrapped in the cellophane of scientific purity may experience a squeamish shudder when Sarton brings before them the ghosts of some who have gone before. Sarton's first Volume carried the development of science from poet to poet —from Homer to Omar. The latter besides producing the incomparable Rubyiat, enunciated a distinctly modern philosophy of life, and produced one of the most accurate calendars that has ever been constructed, more exact than our present Gregorian system of keeping track of the rotation of the earth around its axis and around the sun.

The three typical figures in science at the opening of the twelfth century were William of Conches, Abraham Ibn Ezra (the Rabbi ben Ezra of Robert Browning) and Ibn Zuhr: a Spanish Moslem, a Spanish Jew, and a Norman scholar. Ibn Zuhr was the descendant of a distinguished line of physicians, and is considered by Sarton as one of the greatest clinicians since Galen. His *Taisir* is one of the most important books in the history of medicine. Guilelmus de Conchis, translated by the English William Shelley, symbolizes the realistic spirit of the newly founded school at Chartres.

During the period covered by this volume (from Rabbi ben Ezra to Roger Bacon) two revolutionary discoveries were "sweeping" over Europe —gunpowder and the Hindu system of numbers, embracing the altogether revolutionary concept of the "empty column"—the zero. It took several hundred years for these inventions to be generally adopted and applied. The extreme slowness of the adoption of such obvious improvements appears to be an inborn human characteristic so often is it manifested. In respect to another invention Sarton has this to say:

> Paper money was printed in Chinese and Arabic in 1294 at Tabriz. The invention of block printing was then already old—the Chinese had completed it in the first half of the eighth century if not earlier still—but this is the earliest record of it in Islam, and though it is much later than the original invention, it is also much anterior to western printing. This is a very good illustration of the slowness of human progress. It is not always slow, but for some mysterious reasons the human mind seems to resist certain innovations as much as possible. Here was a practical invention of a very simple nature; its advantages—economy of labor and standardization—are obvious to us. How is it that it took more than six centuries for so simple and fruitful an idea to travel from China to western Europe? No explanation of that extraordinary delay can be given, except an utter lack of interest in the idea and instinctive resistance to it.

Those of us who chafe at the slowness of some of the self-evident applications of biology to human affairs, may take heart at these observations. However, applications of the physical sciences have so speeded up the tempo of existence that racial adjustments must be made more rapidly today than in the twelfth century. Thus a speedier and more consciously intelligent adaptability becomes increasingly necessary to avoid the racial consequences of adverse selection. If "Progress" is hastening the day of some hoped-for millenium nobody is very clear about, may not decay be also accelerated?

Those who are inclined to feel that conditions today "couldn't be worse" and to hint darkly of "Revolution" (with a capital R) as a mystical cure for the evils of the body social may well ponder the following:

> An interesting example of this struggle was given in the period under consideration by the nonconformists who preached the Eternal Evangel of Joachim of Floris. Their religious and social radicalism was condemned by the Church in 1255, but not suppressed. To stop the rebellion of those passionate hearts it would have been necessary to cure the unspeakable evils of the time, and this was beyond the power of the church. Social and spiritual conditions were terrible, the lot of the poorer people (i. e. of the great majority) was exceedingly miserable, personal security was very low, there was no hope for man but what the church could give him, and if the priests disappointed him, his own soul must create a new faith or share his body's starvation. A more striking revolt even was that of the Battuti, whole

bands of half-naked men who crossed the towns scourging themselves by way of penitence, self-debasement, and edification. Their exaltation was as contagious as a disease, and their bands increased in numbers not only in Italy but in many other countries, spreading ecstasy, dissatisfaction and terror everywhere. The fervor of the Italian Battuti manifested itself also in poetical form, and we owe to its inspiration one of the greatest poets of the Middle Ages, Jacopne da Todi. I wish that the scholars who magnify every evil of our own days and idealize the past beyond recognition, would bear in mind these pathetic and frightful processions of Battuti. A spiritual revolt of such magnitude, and characterized by such frenzy, can only be explained by the intolerability of social circumstances.

Conditions today are not perfect. It is not surprising that a race that took three hundred years to adopt the Hindu numerology will take several generations more to work out a "planned society." Nevertheless, granting all the criticisms that are levelled at our social structure, it remains true that average conditions today, as compared with conditions of the masses throughout most of the history of the race, are not bad. This is not an argument against still further improvement. It may be an argument against pettishly proposing to knock our "obsolete society" into small bits, in the hope that a better may spring, Phoenix-like, from the wreckage. Starting at scratch is never so simple in fact as it seems on paper, and the evocation of capitalized abstractions is like calling genii out of bottles,—easy to start but hard to stop! That a great majority of gene-mutations are lethal in their effects may be an analogy whose social implications need to be pondered ere we too frantically jiggle the foundations of society.

Twelfth Century Botany

Biology in the twelfth and thirteenth centuries was not greatly advanced beyond Aristotle. The greatest contributors were the Chinese. Albert the Great (1193-1280) Sarton considers to have been the greatest scientist between Pliny and the sixteenth century. His *De Vegetabilibus* and his *Zoology* in 26 books are considered his most important works. St. Thomas Aquinas (1225-1274) may be credited with being another "discoverer" of sex in plants, as noted in the following quotation:

I have just discovered a curious passage relative to the sexuality of plants in St. Thomas' commentary on the Book of sentences of Peter the Lombard. I quote it verbatim:

"In his enim quae habent vitam perfectam, distinguuntur agens et patiens in generatione propter perfectam generationem in eis. In plantis autem quae imperfectam vitam habent, est in eodem utraque virtus, activa scilicet et passiva: quamvis forte in una planta dominetur virtus activa, et in alia virtus passiva: propter quod dicitur etiam una planta musculina, et alia feminina." (Sancti Thomae Aquinatis Commentum in Quatuor libros sententiarum; Liber III, Dist. III, Quaest. II, Art. 1; Opera ommia ad fidem optimarum editionum accurate recognita, Tomus VII, p. 42, Parmae, 1857.)"*

It is not surprising that these views of the Angelic Doctor have remained unknown to botanists and historians of science, for who would hunt for them in that ponderous commentary? The article in which they appear is entitled "Utrum Virgo aliquid active ad Christi conceptionem operata fuerit." Considering that many people had an empirical knowledge of the sexuality of certain plants (dates and figs) from time immemorial, the astounding fact is not that some scientists or philosophers like Theophrastos, Pliny, Nizāmi, St. Thomas had a vague notion of plant sexuality, but that one had to wait until the end of the seventeenth century (Rudolph Jacob Camerarius, 1694) for the transformation of that vague notion into scientific knowledge.

It is clear from the above that the Angelic Doctor was one of those whose views on sex in plants were verbal and philosophical rather than

* "Indeed, in these (animals?) which have a perfect life, because of their perfect mode of propagation, those that are active in the process of begetting are distinguished from those that merely endure. In plants, on the other hand, which have an imperfect life, there is present in the individual each capacity (namely, active and passive), although by chance the active power may dominate in one plant and the passive in another: for which reason the one plant is said to be masculine, the other feminine."

physiological. This passage gives us perhaps the earliest reference to the use of the words "masculine" and "feminine" in connection with plants, but it shows no comprehension of the biological implication of these words.

One could go on endlessly. Over two thousand pages have so far been published in this monumental work, which is not, after all, a *History of Science*, but only an Introduction! We are said to live in an Age of Science culminating in a Century of Progress, but this is perhaps an overstatement. When the first Paleolith induced a surplus of dead mammoths through the revolutionary discovery that he could increase the acceleration of a spear by the elasticity of a hardwood stick, doubtless the bystanders said: "Look what this Age of Science has let us in for! Dead mammoths all over the place, and killed in such an unsportsmanlike way!" Science does change our outlook in important and in trivial matters. It also sometimes transmutes the trivial into the important as this quotation from a child's book of a hundred years ago suggests:

> Lucy was a very kind little girl. She never beat her little kitten, or set her foot upon a spider. Sometimes when she was eating her bread and milk, a hungry fly would light upon the edge of the bowl, and try to drink. Little Lucy never knocked him into the milk to see him struggle and drown there; but she would say to him:
>
> Drink away, my little fly,
> You may drink as well as I.

Today we swat the fly instead of drowning him in the milk,—hard on the fly, of course, but a quick and painless death. As a result twentieth century Lucys have a vastly increased expectation of avoiding a slow and lingering visitation of that Providence whose inscrutability in Lucy's time it was sacrilege to question, even in a typhoid epidemic.

Let us close our eyes for a moment and try to see things in a very simplified manner, as they would appear from a great distance, in a sort of vision. The stately chariot which carries the highest hopes and the noblest thoughts of mankind has been stopped to change horses in the neighborhood of an inn. The old Muslim postillions are being thanked and new ones are taking charge. The chariot is stopped, but the fresh horses are pawing the ground impatiently. A last glass to the driver and the barmaid bids him Godspeed. In a moment they will be gone. It is the same old chariot, but the horses and postillions are changed from time to time, and the people riding in it change too, one by one. . . . . But, mark this, *it is a chariot that never comes back*. It goes on and on as the spirit of mankind moves it; it has been driven by Greeks, by Romans, by people of all kinds, lately by Muslims, now by Jews and Christians. Nor does it matter much who drives if it goes safely forward in the right direction.

And so the Coach of Science goes on with the good Doctor hurrying after it to bring the Introduction up to date. In the next volume he must follow it through the time of that great applied scientist, who said: "Sail on" in the face of mutiny of crew and compass. He will dissect the times of that great destroyer of false "truths," who whispered in the shadow of the stake, "it does move," and whose doubting mind brought forth a new universe in spite of the Inquisition.

Perhaps when volume III issues from the press this reviewer will have finished reading the second volume of the Introduction—frankly, he has not done so yet. To take it all at a gulp would be like trying to swallow the Atlantic Ocean.

It is perhaps too much to hope that all students of science will read all of this *Introduction* to the history of their chosen field: they should all at least be exposed to it. Even a glimpse of the groups of gallant gentlemen whose efforts have given us that great Coach of Science must add to enthusiasm and strengthen scientific *esprit de corps*. The coach will not lack drivers as long as human beings remain distinctively human, and willingly risk everything, even life itself, to satisfy their prying, irreverant, dangerous, and altogether disquieting curiosity, which the Paleolithic mind, ancient and modern, keeps insisting we would be so much better and happier without!

R. C.

LEFT-HANDEDNESS AND STUTTERING

BRYNG BRYNGELSON AND THOMAS B. CLARK*

WHEN external factors have a large influence on the expression of a character, it becomes a difficult matter to determine the significance of a hereditary predisposition. In the case of hereditary tendency to stutter, such a tendency may, in some instances, never be revealed. In others, according to Travis[5] and unpublished data of Bryngelson, stuttering is manifested, when the native physiologic lead, as indicated by the preferred hand, is shifted to the opposite side, i. e., when a normally left-handed child is compelled to use the right hand. The opinion that stuttering may result from imitation of parents or associates who stutter is apparently without foundation.

The literature of human heredity contains reports on the inheritance of left-handedness and of stuttering in separate family lines, but little attention has been given to the study of these two traits in the same family lines. Two unrelated family trees involving left-handedness and stuttering have been compiled and studied at the University of Minnesota Speech Clinic within the past year and are here presented. The histories revealed no need of considering accidents and diseases as having played any part in the causation of stuttering.

In the interpretation of these data three hypotheses are suggested regarding the manifestation of left-handedness and stuttering. First, these two traits may be the manifestations of two independently inherited characters. Second, left-handedness may have been the result of an inherent dominant physiologic lead in the right cerebral hemisphere, and stuttering may have been produced by the alteration of this native unilateral lead. The usual practice of shifting a left-handed child to the non-preferred right hand could be said to be responsible for the changing of inherent neurophysiological patterns in the brain. Third, stuttering may have been manifested by a lack of a dominant physiologic lead in either hemisphere, essential for a native hand preference. This condition is known as ambidexterity. In the light of recent knowledge[5] it is probable that the latter two conditions are the exciting factors in stuttering. They are considered the more important in the family lines here presented since there is an indication that handedness and stuttering may not be independent.

It is entirely conceivable that ambidexterity in some individuals may be the result of less stubborn left-handed tendencies not responding to complete right-handed training. In others there may be an inherent degree of handedness varying from one extreme to the other. In generation *III* in Figure *7A* the former case is thought to be operative and, consequently, the cause of the large amount of ambidexterity. Note that *III-8* in this family is the only truly left-handed individual of the siblings.

It is of interest to note in Figure *7A* that, with one exception (*IV-11*), left-handedness (considering the ambidextrous individuals as originally left-handed) has appeared in the males as a sex-limited character. In the second family (Figure *7B*), no such inheritance is apparent, the handedness being equally distributed between the two sexes. A lower percentage of ambidexterity appears in Figure *7B*, and it would seem that the process of shifting is more complete in the second family than in the first, Figure *7A*.†

In Figure *7A*, with one exception (*IV-3*), all the ambidextrous individuals either stutter or, like *IV-5* and *V-1*, are afflicted with retarded speech.

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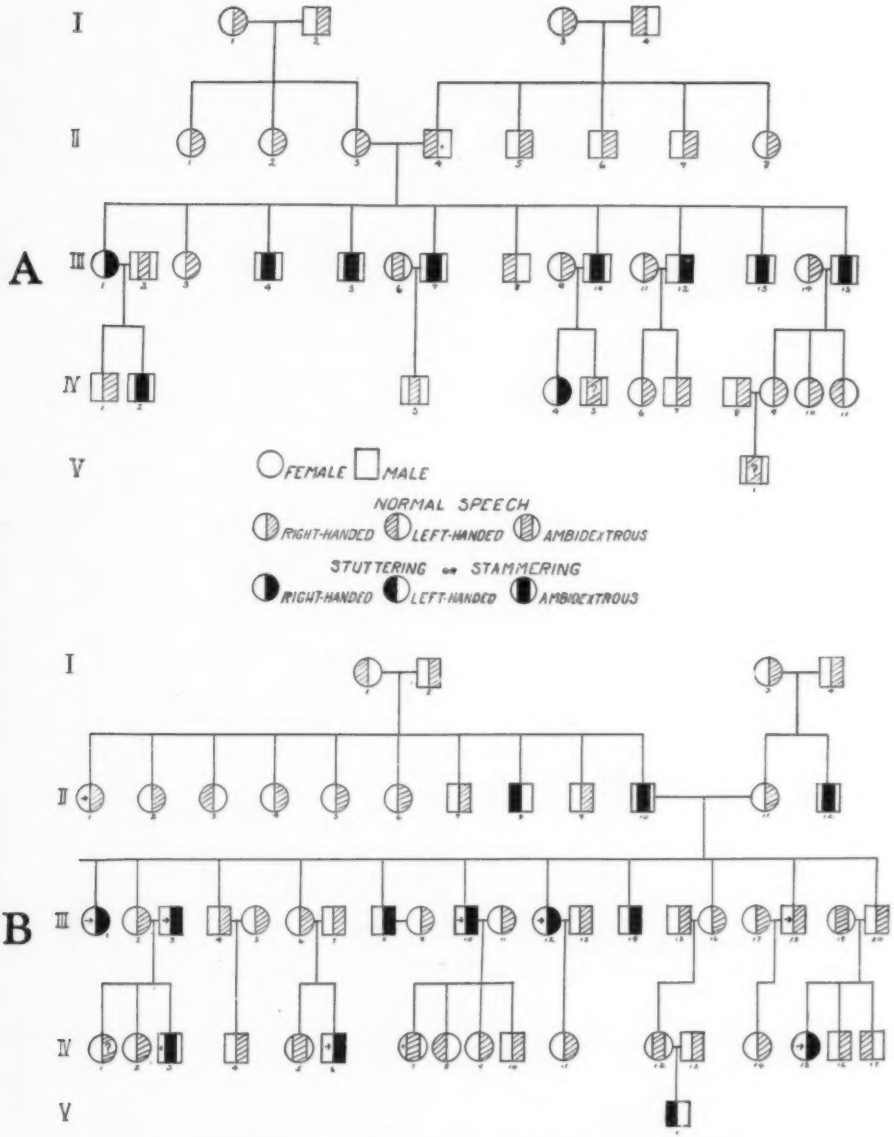
†The small arrows in Figure 7B indicate shifting of handedness from left to right.



TWO PEDIGREES OF LEFT-HANDEDNESS AND STUTTERING

Figure 7

Stuttering is one of those characters that appears to have a genetic background, complicated by environmental influences. It is suggested by these pedigrees that stuttering is brought into expression only when a naturally left-handed person is forced in infancy to use his right hand. Such "modified" left handers are indicated by an arrow pointing toward the right.

Of the ten persons in the three generations who are ambidextrous, seven stutter, two have retarded speech, and one has good speech.* The condition found in Figure *7B* is somewhat comparable. With the exception of *II-1*, all of the shifted cases stutter. Male *III-18* stuttered in childhood. None of the ambidextrous females stuttered, while three such males showed this anomaly.

It is generally considered that left-handedness is recessive to right-handedness. From the report of Chamberlain,[2] however, it appears that the inheritance of left-handedness is not such a simple condition as Jordan[3] concluded. The inheritance in the families here reported is not clear-cut, but a recessive interpretation best explains the transmission of the character to the offspring by right-handed parents. The character is relatively common and it is possible that the normal individuals of these two families which transmitted left-handedness married heterozygous normals. A genetic explanation of stuttering is difficult. If it is inherited as a separate entity, and the evidence is not clear on this point, it is probably a recessive trait and in many cases brought into expression by the factors already mentioned.

While it appears reasonable to regard left-handedness and stuttering in these families as recessive traits, the possibility of dominant inheritance should also be considered. If the ambidextrous individuals are included it will be observed that the population closely approaches the 50% expectation if there is included among the left-handed individuals *IV-9* in Figure *7A* and *III-6* and *III-16* in Figure *7B*. If, as has been suggested, stuttering needs the cooperation of environmental influences in order to make it manifest, the trait will probably appear in less than the expected 50% of the siblings. Considering as potential stutterers the three individuals in Figure *7B* (*III-6 III-16*, and *IV-12*) who, though not stutterers themselves, had stuttering offspring—this expectation is essentially realized.

On the basis of dominant heredity it is assumed that the right-handed, normal-speaking females who, in conjunction with normal males, produced abnormal offspring, be genetically left-handed or stutterers. This condition is not without support. Chamberlain found 1.57% more male than female left-handed individuals. Schiller[4] has stated, as a result of her study, that left-handedness appears more frequently in males than in females. This fact is also borne out by the senior author in an unpublished study of 2,000 individuals in the population at large. Out of a total of 1,029 males, 46 were left-handed, or 4.47±.63%. Out of 971 females, 26 were left-handed, or 2.68 ±.51%. The computed difference is 1.79±.82%, which is significant in the light of the standard error. From the above population with the same distribution between the two sexes, Bryngelson found a sex difference in the frequency of stutterers. There were 58 males, or 5.64±.72%, and 27 females, or 2.78±.52%. The difference of 2.86±.89% is significant. Travis[5] has called attention to data obtained in the Speech Clinic at the State University of Iowa relating to stuttering and left-handedness, which show a higher frequency in males than in females. These data suggest that some females may be carriers in whom the traits are not revealed. On the other hand, the data may indicate that some females are more easily shifted from left to right without any consequent stuttering.

Until further knowledge is available concerning ambidexterity it is doubtful if all such individuals should have been included in the left-handed class. The inclusion of the right-handed females, where the trait skipped a generation, is also open to question. The fact that

*Note that *III-1* and *III-12* classed as stutterers have slovenly speech.

inheritance of left-handedness is not always direct from parent to child strongly indicates a recessive character, though dominance might be masked by the forced change in handedness of a genetically left-handed person.

A close relationship between stuttering and handedness was found by Bryngelson.[1] On a later check this study showed that in 127 school children who stuttered, 81% had been shifted from left to right in handedness. Seventy-five per cent of these children had relatives who stuttered. This seems to support the hypothesis that handedness and stuttering are not independent traits.

More data are necessary in order to determine whether or not all shifted cases have an inherent predisposition to stutter. However, it is evident that in studying the inheritance of stuttering in a family the history of handedness must be considered.

Literature Cited

1. Bryngelson, Bryng, 1931: Treatment of Stuttering. *Jour. of Expression*, 5: 19-26.
2. Chamberlain, Herbert D., 1928: The Inheritance of Left-handedness. *Jour. of Heredity*, 19: 557-559.
3. Jordan, H. E., 1911: The Inheritance of Left-handedness. *Amer. Breeders' Mag.* II: 19-29 and 113-124.
4. Schiller, M., 1932: Probleme um die Linkhändigkeit mit Untersuchungen an Stuttgarter Schulkinden. *Zech, f. ges. neur. h. Psychiat.*, 140: 496-516.
5. Travis, Lee Edward, 1931: *Speech Pathology*. D. Appleton and Company, New York.

Through the Microscope

THE SMALLEST LIVING THINGS, *by* Gary N. Calkins, Ph. D., Sc. D., Professor of Protozoology, Columbia University and at the Marine Biological Laboratory. Eleven Chapters. Suggestions for Further Reading. Glossary. Index. 135 Pages. The University Society, New York.

THIS is a popular presentation of some of the more interesting cytological, morphological, and ecological aspects of the bacteria, spirochaetes, protophytes, and protozoans, accompanied by abundant illustrations. The statement is made that all animals are fundamentally alike, rather than fundamentally different, and that principles formulated from the study of heredity in Drosophila are applicable to all types. Certainly in many of the Protista with which this booklet is primarily concerned, there still remains a lack of any proof based on cytological evidence of sexual reproduction. One searches in vain for convincing proof of haploid gametes forming diploid zygotes amongst the lower Protista, such as the bacteria, many protophytes, and many of the lower Protozoa. The methods of genetic analysis have as yet scarcely invaded the Protista and much of the so-called sexual behavior among the Flagellata and Sarcodina is still without even elemental cytological proof. This field is most inviting, since it may ultimately yield data which will still further elucidate the evolution of chromosomes, mitosis, genes, sex, and sexual reproduction. The hypothesis that the phenomena are present throughout the Protista has thus far led to not a few uncritical conclusions based on the substance of things hoped for rather than on skillful technique, and on critically wrought out cytological evidence.

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University of California.

TWELVE YEARS OF STRAWBERRY BREEDING

A Summary of the Strawberry Breeding Work of the United States Department of Agriculture

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A PROJECT for the improvement of existing commercial varieties of strawberries was undertaken by the United States Department of Agriculture in 1920. In that year the first crosses were made at the Horticultural Field Station near Glenn Dale, Maryland, and since that time the work has been steadily expanded to include experimental plantings in other strawberry growing regions of the United States. By May 1, 1932, a total of nearly 75,000 seedlings were growing at the three stations at which the experiments are being carried on: 46,000 seedlings at the Glenn Dale station in Maryland, 19,900 in the cooperative work with the Oregon State Experiment Station at Corvallis, Oregon, and 9,000 at Willard, N. C. In all, approximately 200,000 seedlings have been grown. By the end of the fruiting season in 1933 a total of 3,817 seedlings had been selected as being worthy of further trial (1,880 were at the Maryland station, 862 in Oregon, and 1,075 at Willard, N. C.). Of these 3,817 seedlings, seven have shown themselves superior to existing varieties in one or more respects. These have been named and introduced to the trade. Of the remaining selections, about 1 200 are still being maintained for further observation and experiment, as being of possible value themselves or as parents of further crosses.

It is proposed in this article to discuss the methods employed in this work, and it is hoped in a later article to summarize the results to date and to discuss the probable value to the plant breeder of the various species of strawberries which are available for breeding work.

The primary purpose of this project was the improvement of existing commercial varieties of strawberries. In the early years of the work three specific objectives were in view and these have been added to as the years have passed. These immediate objectives were: (1) the development of a berry of superior dessert quality, suitable for culture in the eastern states; (2) the development of really satisfactory canning varieties of strawberries; (3) the development of varieties suitable for preserving by refrigeration. The varieties already introduced are the result of the crosses made in 1920 and 1923. To some degree they express the solution of the problems that were believed to be of outstanding importance at the beginning of the work.

A survey of all the commercial strawberry regions of the United States made by the senior author during the years 1914 to 1917 showed that the leading dessert variety was the Marshall. The tremendous differences in the quality of berries offered to the public is indicated by the range of prices noted on the Boston market during this survey. Ordinary market berries were selling for eight cents a quart, while berries of the Marshall variety were offered at thirty-five cents a quart. The difference in price may be taken as an indication of the difference in quality and flavor of the berries. The Marshall, however, is very difficult to grow in the East, and high quality varieties suited to east-

ern conditions were badly needed. Three of the varieties resulting from the experiments described here have been introduced to meet this need. These, the Southland, Dorsett, and Fairfax, are of much finer dessert quality than most commercial varieties and they are suited to culture under a much wider range of conditions than is the Marshall.

The varieties adapted for eating as fresh fruit are not satisfactory for canning, as cooking tends to alter the flavor and the berries lose their shape and color. For canning purposes a variety is needed having a firm flesh and a color which would not be considered the best in the raw state. After very extensive canning experiments with a large number of seedling selections, the Redheart has been selected as being a distinct addition to canning varieties. In recent years the development of artificial refrigeration has opened up a new industry—that of preserving fruit by freezing it with sugar. Neither the dessert varieties nor the canning varieties are suited to refrigeration. After much experimentation in cooperation with home economics and refrigeration experts, the Blakemore was introduced to fill this need.

The problems peculiar to the different sections of the United States have been studied and the breeding work has been expanded and redirected in an attempt to meet these needs. Thus, nearly all the berries raised in the extreme south are shipped to northern markets, where in the late winter they are sold for high prices, yet the varieties grown in the southern states have been without exception very tart, suitable for use in preserves or with relatively large amounts of sugar, but not for eating out of hand. Tests under short days in the greenhouse, however, indicate that it may be possible to raise sweet, highly flavored varieties even in Florida under the short days of low light intensity of winter.

Again, though hundreds of carloads of strawberries are shipped each year from Florida to northern markets, a series of recent Florida winters with exceptionally severe conditions—low and high temperatures, droughts and storms—have emphasized the unusual requirements needed in a variety for that region. *Fragaria chiloensis,* the species which is native only on the beaches of the Pacific Coast, from Oregon to Chile, has many of these requirements. It endures the long droughts of western summers and it grows vigorously during the short days of northern winters in the greenhouse. Its leaves are uninjured by severe cold but they do not endure the humid heat of eastern summers. Hybrids between *chiloensis* and varieties that withstand high summer temperatures are therefore being made. Among these it is hoped that varieties may be found with all the required characteristics. The Southland, a *chiloensis* hybrid originated in these experiments, has some of the characteristics sought—especially foliage that endures the changing conditions of southern winters.

In the Pacific Northwest, the Marshall, which originated in Massachusetts and is adapted to the Northwest, is still the principal variety. Though the standard of dessert quality in the United States and though it produces well in the Northwest, its growth habits are not adapted to the climate of that region. In western Oregon it starts to differentiate fruit buds about September 1, which is about the end of the dry period but before fall growth has started. It ceases to make much growth by November and its runners and leaves are killed by the first severe weather. In contrast, the variety Ettersburg 121 does not start flower, but development under these conditions until November 1, after the fall rains, and after it has made a vigorous vegetative development. It continues growth during the winter whenever growing temperatures occur, and most of its leaves

stay green all winter. Varieties better adapted to the Northwest, with plant characteristics more like those of Ettersburg 121, are needed. Both the Corvallis, originated by the Oregon State Agricultural College, and the Redheart, originated by the U. S. Department of Agriculture, show some of the desired plant characteristics. Hybrids of cultivated varieties with selections of the wild species exhibit these special qualities to an even greater degree.

Methods

During the first few years the breeding work at Glenn Dale, Md., was done in the field under cages of wire screen, cloth or under suntraps. Making large numbers of crosses in the field proved very laborious, and the crosses had to be made at a time when other work demanded attention. On several occasions most of the flowers were killed by unseasonable late frosts so that the work had to be done all over again. For these reasons field pollination has practically been discontinued, and most of the crossing is now done in cold or heated greenhouses.

For breeding in the greenhouse, runner plants of the selected varieties are usually potted—first in thumb pots in August*; later, in September, in rich soil in 5- or 6-inch pots. If more plants of any variety are needed than were originally potted, they are dug at any time before spring, with a ball of soil around the roots of each plant. Such plants do not ordinarily produce as many flowers as the plants potted earlier, but are often used.

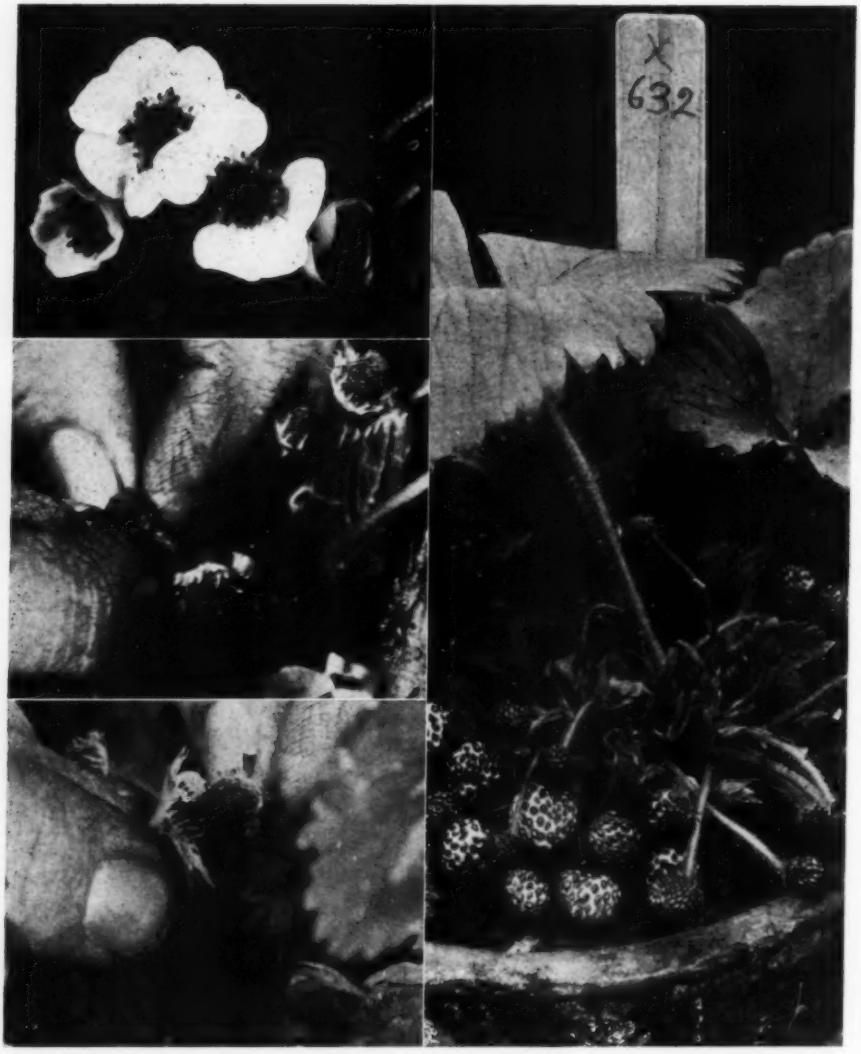
Unheated greenhouses have been used for most of the work in Maryland. (Fig. 9*B*.) Under these conditions the flowers open during March and April, about a month earlier than in the field. The two benches shown are each about 4 feet wide and make it possible to do the crossing with the plants in place, or for greater convenience, the pots may be lifted to the hollow tile wall while the actual crossing is done.

At Corvallis, Oregon, heated greenhouses have been used for the breeding work for the past three years. All of the earlier breeding was done out-of-doors, as under Oregon conditions it was considered cheaper. The low light intensity of some Oregon winters makes it somewhat difficult to obtain good pollen in the flowers of some varieties in the greenhouse. Four to six hours of electric light have been used during the winter to supplement the daily photoperiod. (Figure 9*C*.) This additional light has been found to be particularly necessary if the plants are

TABLE I.—Characteristics Which Must Be Given Consideration in Selection of Varieties.

Plant	Resistance to root rots
"	Resistance to yellows
"	Resistance to crinkle
"	Resistance to verticillium wilt
"	Resistance to drought
"	Resistance to frost
"	Free runner production
"	Adaptation to short days in south
"	Adaptation to long days in north
"	Needing no rest period in south
"	Productive
Foliage	Resistance to leaf spot
"	Resistance to leaf scorch
"	Resistance to dendrophoma spot
"	Resistance to aphis
"	Resistance to mildew
Flowers	Perfect with much pollen
Berry	Attractive
"	Good size (very large in Central California)
"	Early in south
"	Late in north
"	Quick ripening in south
"	Uniform size
"	Uniform shape
"	Uniform in ripening
"	Resistance to fruit rots
"	Skin tough
"	Skin glossy
"	Flesh solid
"	Seeds yellow
"	Color light red for preserving
"	Color not turning dark
"	Color deep red for canning
"	Flavor aromatic
"	Flavor acid for canning and preserving
"	Flavor subacid or sweet for general market

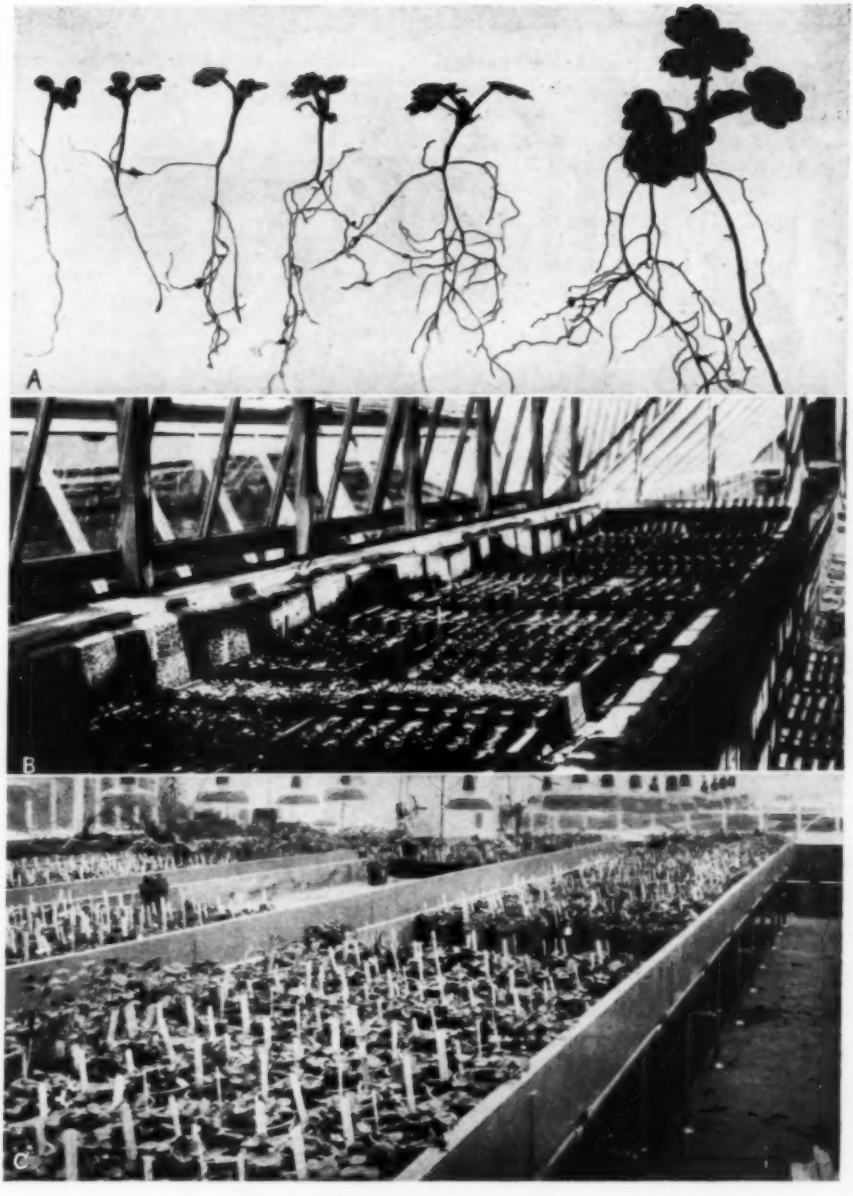
*In Oregon, because of the summer dry season, runner plants can not usually be rooted before October 1.



POLLINATION OF STRAWBERRY FLOWERS

Figure 8

At the left are shown three phases in the artificial pollination of strawberry flowers. At the top are three fully opened flowers with the petals intact. The petals and calyx are removed and the flower is emasculated with the fingernail (center). Below is shown the actual process of pollination. The flower at the left, from a plant chosen as the male parent of the proposed cross, and having stamens full of ripe pollen, is pressed against the flower to be pollinated (right) and twirled between the fingers. The plant shown at the right is shown after pollination has been completed and the fruit has begun to develop. The pollinated fruits are identified by the fact that they have no calyxes. All the flowers of this plant were crossed with a single male, number 632, as is shown on the label. When more than one pollen parent is used in making crosses on a single plant, the fruit must be identified with labels, which greatly increases the labor of making crosses.



STRAWBERRY SEEDLINGS

Figure 9

Strawberry seeds most of us have encountered, but the seedlings—they much less frequently come under observation. Above are shown (*A*) various phases in the development of strawberry seedlings. These complete the early stages of development in flats (*B*) under lath shade. Later the seedlings are potted preliminary to planting in the field (Figure 12). (*C*) Plants under electric lights for part of each night in winter to force flowers for breeding.

brought into the greenhouse before January, that is, before the cold of winter has broken the rest period.

Pollination Technique

The actual crossing is done much more easily in the greenhouse than in the field. There are several reasons for this: (a) it is possible to stand erect or sit while emasculating the flowers and applying the pollen; (b) in the greenhouse, many perfect-flowered varieties produce primary, secondary, and even tertiary flowers having no pollen-bearing stamens so that the emasculation of such flowers is unnecessary; (c) the pots can be carried to different parts of the greenhouse to save time; (d) insects do not usually interfere so that the plants or flowers do not need to be covered; (e) the stamens do not open before the petals unfold, making it possible to emasculate and pollinate at the same time, just as flowering starts.

When emasculation is necessary, the thumb nail is generally used to remove the stamens, corrolla and calyx at one operation. If done with ordinary care no resulting injury to the pistils has been observed. When working with small flowers, such as those of *F. vesca*, sharp pointed scalpels or tweezers sharpened to a cutting edge are used to cut the flower parts off. Even though emasculation is not necessary, the calyx and petals are always torn off when the flowers are pollinated in order to identify the crossed flowers. (See Fig. 8.)

Especially when grown under glass, the first flowers to open on clusters of many varieties are pistillate (the stamens, if present, do not contain good pollen). For this reason it is often difficult to obtain pollen at the beginning of the season. The first flowers of Marshall, Redheart, Fairfax (and usually of Southland and Ettersburg 121) contain abundant pollen, while the first flowers of such varieties as Howard 17, Missionary, Blakemore, Bellmar, and the everbearing varieties usually contain none. The primary and secondary flowers contain far more pistils than the later flowers on a cluster, and hence can set far more seed when pollinated. Thus every effort is made to pollinate the earliest flowers on each cluster, using the later flowers of the perfect-flowered varieties as sources of pollen.

To obtain pollen the practice has been to pick flowers having pollen-bearing stamens just as the petals are unfolding. The stems are left about ¼ inch long and if the pollen is to be used within a few hours the flowers are allowed to wilt. As they wilt the anthers break open and more pollen is available than if the anthers dehisce on the plants. If pollen is needed later it can be held for from one to four days by placing the flowers in shallow vessels of water and allowing them to open. When examination shows the anthers fully opened, the flowers are used directly on those to be crossed, being held so that the stamens touch the pistils. The flower is twirled by its stem in such a manner as to cover all the stigmas with pollen. A flower with abundant pollen may be used to pollinate four to six flowers, or even more. Other breeders first collect pollen and then use camel's hair brushes to apply it. When pollen is scarce the brushes may be used to advantage. There has seemed to be a greater chance for error through accidental mixture of pollen when using brushes than when using the flowers themselves.

The comparative ease with which an abundance of pollen may be obtained and the readiness with which blossoming may be advanced or retarded by placing the potted plants in warmer or cooler parts of the greenhouse, and by bringing in additional plants from the field, have made storage studies of pollen unnecessary. It has been observed, however, that the pollen soon spoils under moist conditions, but when kept dry it apparently has been fully effective even when held for several days. Crandall* has reported slightly better results with pollen four days old than with fresh pollen.

Handling the Seedlings

After being pollinated, the flower, flower cluster, or plant is marked to indicate the cross. (Fig. 8.) When large numbers of one or more crosses are made, all flowers on entire plants or rows of plants are pollinated with pollen from the same male parent and a single label is used for each plant. Thus the work of labeling crosses is greatly reduced.

The berries are picked as soon as they are fully mature. Usually the fresh berries are mashed in dry propagating sand to separate the seed, and the mixture of seed, pulp, and sand is sowed in flats and pots at once. In

*Crandall, C. S. 1912. The vitality of pollen. *Proc. Soc. Hort. Sci.* 12-130.

1932 the crossed berries in Oregon were placed in freezing storage and held for eight months before sowing. At no time is the seed allowed to dry out. The flats and pots are filled with good potting soil to within about one inch of the top, then about ½ inch of propagating sand is packed down solidly on top of the soil. The seed and sand mixture is then sown evenly and packed, and finally ⅛ inch of sand is sifted on top. Soil to which commercial fertilizers have been added is to be avoided for it may prevent germination just as in the case of seeds of other plants.

No tests of the optimum temperature for germination have been made, as good results have been obtained at all temperatures encountered except perhaps in 1925 when the temperatures for several days after sowing were above 100°F. Poor germination seemed to result from such temperatures. Many of these seed flats were kept until the following winter when, after a rest period, additional germination occurred. To keep the top of the flats and pots moist they are usually shaded until the seedlings appear.

The quickness of germination varies greatly depending chiefly on the mother parent. Seed of *Fragaria virginiana* germinates more rapidly than any other we have observed, seedlings sometimes appearing four days after sowing.* Seed of some garden varieties and of some strains of *F. chiloensis* may not germinate for two or even four weeks.

The seedlings are usually potted or flatted when they reach a size convenient for handling. (See Figure 9*B*.) If left until they are crowded, loss from the damping-off fungus may be serious. Paper cups, or more exactly 2×2 inch paper collars, are usually used for potting at the Maryland and North Carolina stations. Plants in these paper collars occupy less space than those in thumb pots or in flats and there is less danger of loss from drying out than in thumb pots. At the Oregon station where paper collars are not used, the plants are pricked into flats, two inches apart. As soon as large enough the plants may be set in the field. Those in the paper collars are planted with the collars still intact, while the soil of those in flats is cut into 2-inch squares for field planting.

Field planting methods vary according to climatic conditions. In Maryland, during the early years of the experiments, the seedlings were set five feet apart in rows 3½ feet apart, and a matted row was allowed to form. Since 1927, to permit horse cultivation they have been set four feet apart each way and a small number of runners allowed to form around each seedling. At the Willard, N. C., station, as far as possible, the plants are set in August at intervals of about 18 inches in rows 3½ feet apart. If any runners start they are cut off. Selections are made the following spring when the seedlings are less than a year old. At the Oregon station the plants are set during the fall, winter, or spring, spaced 18 to 24 inches in rows 3½ feet apart. All runners are removed during the following summer. There the selections are made, as in Maryland, when the seedlings are about two years old. In making selections in North Carolina and Oregon, the merits of the seedlings are judged on the performance of single plants only, while in Maryland a small mat of plants of each seedling may be observed.

Selection of Seedlings

If records are not to be kept of each seedling of a cross, the most satisfactory method has been to go through the field at the beginning of the ripening season cutting out those plants that obviously would not become valuable commercially (Fig. 10). Such undesirable plants may be dwarfs, or subject to mildew, leaf spot, leaf scorch, Dendrophoma leaf spots, Rhizoctonia root rot, or they may produce little or no fruit, or fruit that is poorly shaped, small in size, or soft, or that ripens unevenly, or is of poor color, etc. The remaining seedlings can then be studied in more detail and selections made on the basis of other fruit characteristics such as dessert quality, firmness, color, season, etc.

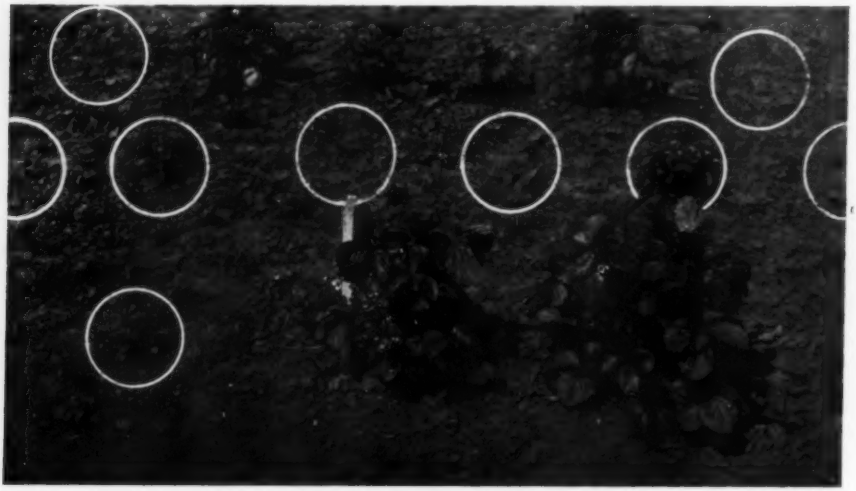
The number of selections made varies greatly but is rarely over ten per cent and is usually less than two per cent of the seedlings fruited. The exact

*See Fig. 2, Darrow, George M. Progress in Fruit Breeding. *Journal of Heredity*, 18:7, 1927.

AFTER "JUDGMENT DAY" IN THE STRAWBERRY FIELD

Figure 10

This photograph shows what is left after selection has been completed. The plants that have been "found wanting" have been destroyed, and of the thousands of plants originally in the field, only a handful remains. In all, over 200,000 seedlings have been tested in the breeding experiments of the U. S. Dept. of Agriculture. Of this tremendous number only about 1,200 have survived the primary and secondary stages of selection. Only seven have been chosen as having enough promise to be distributed as named varieties.



NOT ALL SELECTION IS BY HUMAN AGENCY

Figure 11

The white circles show plants affected by rhizoctonia root rot, or they mark the place where plants grew before they succumbed to its ravages. The two plants in the foreground are part of a progeny that was not attacked. Resistance or immunity to pests and diseases is an important factor in plant breeding. A selection of great apparent promise may be valueless in the field because of its susceptibility to such an organism as that which practiced such effective selection in the above picture.

THREE STAGES IN SELECTION IN THREE REGIONS

Figure 12

Selection passes through several phases before a promising seedling is seriously considered as a possible new variety. The seedlings that are chosen in the preliminary selection (Figure 10) are planted for further observation and multiplication. This eliminates many plants. In the view above (*A*) is shown such a second trial field. Many seedlings were eliminated in the field shown by being killed by drought. Others were discarded for various reasons. The survivors are planted in short rows (*B*) for further observation. The best of these selections are given field trial in a fifty-foot row (*C*). This shows such a final test field with oats sown between the rows to act as winter mulch and to prevent erosion. (*A*. North Carolina, *B*. Oregon, *C*. Maryland.)

numbers in various years will be given in a later article. When a seedling is to be saved for further testing, it is given a serial number by which it is thereafter known.

As soon as conditions are favorable after the fruiting season, the selections are transplanted into rows and a second test is made on a larger scale. (See Fig. 12). This done as early as June or July at the Maryland and North Carolina stations. If all leaves are picked off, very few plants are lost when transplanted into moist soil. During the exceptionally dry season of 1932, only 3 out of 176 were lost at the Maryland station, while at the North Carolina station where only one plant of each selection was available for transplanting, the loss was 215 out of 820 selections. After the second test some plants may be selected for wider testing or for special tests for such purposes as preserving or canning. The second test row is usually not over 25 feet long while the later test rows are 50 or more feet in length (Fig. 12*C*).

No fertilizer is used on the rather poor sandy loam in which the seedlings are raised in Maryland. The selections made under such conditions will thrive in the strawberry sections along the Atlantic Coast. The selections under second test, however, are usually fertilized or grown on fairly good soil.

Bases of Selection

The breeder is faced with several problems when he undertakes to decide on the location of his breeding operations. The site chosen on which to grow and evaluate the seedlings and the conditions under which they are to be grown have a very important bearing on the value of the work. If the seedlings are isolated from older strawberry fields the problem of infection and infestation with injurious pests and diseases is greatly simplified. The value of the practical results obtained may be indeed somewhat problematical when we remember that resistance to such pests may be of the utmost importance. When resistance to any insect or fungus pest is to be considered, an extensive and intimate knowledge of its life history and its relationship to the plant in question is absolutely essential. Specialists in entomology or plant pathology must be called in to plan the experiments and to aid in their interpretation.

In general, those diseases which are systemic or those insects which are extremely difficult to control have been omitted from specific consideration and have been kept out of the breeding plots as far as possible. Thus no direct breeding for resistance to the virus diseases, yellows, crinkle, or witches broom, to the strawberry crown mite (cyclamen mite) or to the root, crown, and stem nematodes has been attempted. Resistance to some of these pests may be obtained, as is indicated by the work on the yellows in California by Dr. Thomas. In Oregon some varieties show a marked resistance to "crinkle." Root nematode is also much more extensive among some seedlings indicating less resistance to this particular infection. Between 10,000 and 15,000 seedlings in the greenhouses in Washington representing scores of different crosses seemed to be equally subject to the strawberry crown mite, even though the Marshall in the West may seem a little more resistant to this pest than Nick Ohmer, Capitola, Mastodon, Clark and some other varieties. The stem nematode has been seen on thousands of wild plants of *Fragaria chiloensis* on the Pacific coast, and though many were apparently free, no real evidence of resistance has been observed.

Besides the pests referred to, troubles due to unknown pests are not uncommon and are kept out of the test fields as far as possible. Thus, in 1931 an epidemic fasciation suddenly appeared in some of the seedling fields and hundreds of affected plants were rogued out. This also attacked the cultivated varieties. Many seedlings are killed or are weakened by what seem to be root rots and are of course eliminated.

Recognized root rots are considered to some extent. Thus in a test of some 30 selections in comparison with standard varieties at Corvallis, Oregon, several were

exterminated by Rhizoctonia root rot, many others were severely injured, several were as resistant as the standard varieties, while four were much more resistant than standard varieties and were apparently uninjured (Fig. 11). Certain crosses seem to be especially susceptible to Rhizoctonia root rot (especially crosses with Clark) and others relatively resistant (especially crosses with *F. chiloensis*). Mildew on the leaves, flowers, and fruits of seedlings is a serious problem in the Northwest, and seedlings are selected with this factor in mind. Many selections of *F. Chiloensis* and *F. cuneifolia* are especially susceptible, apparently more so than *F. virginiana*. Seedlings resulting from crosses of these species show inheritance of resistance and susceptibility from the parents.

Leaf Spot

Resistance to leaf spot, though always considered, offers serious complications. In the Pacific Northwest the Ettersburg 121 seems to be more resistant to leaf spot than Marshall. Since the leaves of the former variety survive the mild winters of western Oregon, while those of the Marshall do not, the infection on the over-wintering leaves of Ettersburg 121 is ready to spread to the new leaves as they appear. Under such conditions the Marshall may appear to be more resistant. Again, very slight differences in fertility of the soil, site, time of growth or some other condition may make great differences in the amount of infection.

Thus, at Willard, N. C., early in December nearly every seedling of the crosses that were planted August 6 to 8 was so badly affected by leaf spot that under ordinary conditions they would be discarded, while far fewer of the seedlings set September 13 were severely affected. In one comparison, seedlings of the cross Southland × U.S.D.A. 542 planted in August showed 47 per cent of very severe leaf spot infection, while those set out in September showed only 21 per cent of infection. Three cases have been observed where Blakemore, which is generally more resistant to leaf spot than are Missionary and Klondike, had a more serious infestation than those varieties. Whether this is due to its more vigorous growth in the summer, to soil conditions, or to a different strain of the leaf spot fungus, is not known.

Many records have been made of the prevalence of leaf spot on varieties and seedlings, but these are of limited value unless more is known of the causal fungus and the conditions favorable to infection. In one comparison at the Maryland station, 18 out of 24 selections from the breeding work of the New York Experiment Station, and 24 out of 46 selections from the Oregon station were so badly affected by leaf spot that many were actually killed outright. The infection records on several thousand seedlings of different crosses at Willard on December 8, referred to above, are given below.

When the difference in the amount of infection of the September- and August-set seedlings is considered it is apparent that only general conclusions as to relative susceptibility and resistance of the crosses can be made. It should also be

TABLE II.—Percentage of Seedlings with Severe Infection by Leaf Spot at Willard, N. C.

Rank	Percentage of Seedlings	% Bad Leaf Spot	Date Transplanted
1	Missionary × U.S.D.A. 634	94	Aug. 6 to 8
2	Missionary × U.S.D.A. 1021	94	"
3	Blakemore × U.S.D.A. 634	88	"
4	U.S.D.A. 656 × Blakemore	87	"
5	Missionary × Fairfax	84	"
6	Bellmar × Blakemore	82	"
7	U.S.D.A. 778 × Fairfax	80	"
8	*Fragaria cuneifolia* × Fairfax	76	Sept. 13
9	Missionary × Redheart	75	Aug. 6 to 8
10	Klondike × U.S.D.A. 634	67	"
11	Missionary × Blakemore	61	"
12	Ettersburg 904 × Blakemore	49	"
13	Southland × U.S.D.A. 542	47	"
14	Blakemore × Redheart	41	"
15	Blakemore × U.S.D.A. 1021	45	Sept. 13
16	Blakemore × U.S.D.A. 542	34	"
17	*Fragaria chiloensis* 5-C × Blakemore	24	"
18	Southland × U.S.D.A. 542	21	"
19	Blakemore × Fairfax	13	"

observed that the parents of these seedlings are in general exceptionally resistant to the leaf-spot fungus, yet, under the conditions encountered, the seedlings were especially susceptible.

Resistance to aphids is of importance in relation to the spread of virus diseases as well as because of the damage done by the aphids, the ants that tend them, the weakening of the plants which may be then killed by drought or too high temperature, and the possibility of infection by root rots. In Europe the Leopold, Lefebre, John Ruskin, and Bedford Champion are among the varieties that have been found resistant, while the Royal Sovereign, Duke, Laxtonian, Kooi and others are extremely susceptible to aphids. In England, resistance to aphids has been found to be inherited. The Blakemore has been much more resistant to the root aphid along the Atlantic Coast than other commercial varieties. In a comparison of over a thousand different selections and varieties in Maryland, some 20 to 30 seemed even more resistant than the Blakemore. It was suggestive to find that the Leopold, as well as European varieties received under the names Ideal, Chanzy, Sieger and Marchand, found to be resistant to aphids in Europe were among these. Of the others there were 16 selections from the breeding work at the Maryland Station and two selections from the cooperative work at the Oregon station.

Notable resistance to the bud-weevil has been found in the breeding fields at the Glenn Dale station which can not be wholly attributed to response of the weevil to the amount of pollen in the flowers. In 1930, with the help of W. A. Thomas, the following record of the buds cut by the weevil (using 408 to 744 buds of each) was made:

Variety	*% Cut*
Ettersburg 121	43
Ettersburg 121 (2nd count)	41
F. moschata	42
Heflin	41
U.S.D.A. 542	33
Fairfax	32
Klondike	27
Klondike (2nd count)	18
Dunlap	19
Redheart	18
Missionary	18
Missionary (2nd count)	17
Blakemore	16
Aroma	11
F. chiloensis (of Etter)	10
Chesapeake	8
F. vesca	4
Howard 17 (Premier)	3
Bellmar	2

Though the flowers of Bellmar and Howard 17 contain relatively little pollen and those of Ettersburg 121 and *F. moschata* contain abundant pollen, flowers of *F. chiloensis* and Redheart contain as much or more pollen than Ettersburg 121 and far more than Klondike or Dunlap. Such records indicate that breeding for resistance to this pest may not be incompatible with breeding for more pollen in the flowers.

Temperature Reactions

Survival under the low temperatures in the North as well as under the high temperatures in the South is also important. Low temperature survival may be simpler than high temperature survival where drought, fungi, insect, soil temperature, soil acidity, concentration of the soil solution and other factors may enter in. Resistance to high temperatures (greater than that of Missionary and Klondike) has been observed under the conditions at Willard, N. C., in Bellmar, Blakemore, Dorsett, McClintock, Nancy Lee, Southland, Tennessee No. 21, and some 65 selections from the breeding work of the U. S. Department of Agriculture.

A "STRANGLING" EUCALYPTUS

MARY FRANCIS BAKER

A TREE of *Eucalyptus robusta* planted in southern Florida twenty-five years ago is showing a remarkable and apparently unique example of teratology. A first glance at its peculiarly enveloped trunk gives the impression that the tree has become the unfortunate host of *Ficus aurea*, known as the strangling fig. This is not the case, however; the growth is entirely from the tree itself, and, so far as known, such growth in the eucalypti has never been recorded.

At a height of eighteen feet from the ground a branch-like growth starts downward, soon dividing and forming a number of descending branches which are entirely free from the trunk except at the point of origin and at the base of the tree, where some of the larger ones have formed a union with the trunk. They hang rather loosely, and the hand may be passed between them and the trunk.

A remarkable feature of the case is the fact that this growth started underneath the bark and grew down the trunk of the tree to the ground before breaking through the bark. It was first noticed three years ago, when it had begun to break through the bark a few feet from the ground. Since that time it has continued to break through and to increase in size, until it exhibits the strange appearance shown in the accompanying photograph.

There is no indication of any injury to the tree that might have induced an unusual growth. A branch has been

SECOND-STORY ROOTS

Figure 13

An "aerial root" developing eighteen feet from the ground is a unique feature of this tree. Such roots are characteristic of some genera of plants, notably the figs, but this development appears to have been unknown heretofore in a eucalyptus.

cut off near the point of origin, but this was a sound branch that was removed two years ago.

This tree is one of several of the same species, and of the same age, in the grounds of the public library at Alva, Florida, a town situated on the banks of the Caloosahatchee River, twenty miles east of the city of Fort Myers.

The attention of the writer was directed to the tree by Mr. H. S. English, who has resided at Alva for many years. Mr. English furnished the photograph, and especially desires that someone would offer a satisfactory explanation of this strange growth.

A letter to the Secretary of the Forestry Board of the Queensland Forest Service, Australia, brought the reply that they had never known of such growth in any species of Eucalyptus.

Population Trends and Policies

POPULATION TRENDS IN THE UNITED STATES, *by* WARREN S. THOMPSON and P. K. WHELPTON. Pp. X + 415. Price $4.00. McGraw-Hill Book Company, Inc., N. Y., 1933.

THIS book is one of the series of monographs published under the direction of President Hoover's Research Committee on Social Trends. It presents extended tables and detailed information which could not be included in the report of the committee. In the words of the authors "It attempts to give a more complete picture of population in the United States than has been available hitherto and to project past trends into the future in such manner that the probable changes can be evaluated by those who are interested in doing so." (p. vii.) The United States Census materials constitute the principal source of data and the analysis is confined largely to quantitative problems and their significance.

The beginning chapter is concerned with the growth of population in the United States from the colonial days to the present time. Chapters then follow discussing the distribution of the population, national origins, age composition, sex composition, deaths and death rates, births and birth rates, population growth from immigration and natural increases, probable trends and consequences of future growth, and finally population policy. The volume contains an appendix with seventy pages of statistical tables.

Throughout the book the authors have carefully related the population changes to the major divisions of population such as rural-urban differences, size of community, and regional distribution.

Not the least valuable part of the work is the discussion of the probable future trends and their consequences. Of the several methods which have been used to forecast the probable size and composition of the population in future years, the authors believe that the most promising method for the United States is to make separate estimates for the future trend of birth rates, death rates, and net immigration and to calculate from these assumptions what the resulting growth and population will be. Using this method and trying out several combinations of these estimates, they conclude that the growth of population in the future is certain to be much slower than in the past. According to the minimum and maximum assumptions they predict a population of between 132,500,000 and 134,500,000 in 1940, between 140,500,000 and 148,500,000 in 1950, and between 145,000,000 and 190,000,000 in 1980. The minimum estimate indicates that the population will reach its greatest size (approximately 146,000,000) between 1965 and 1970 and

will subsequently decline; the maximum estimate suggests an increase up to the end of the century.

The concluding chapter is a discussion of population policy. It asserts that consciously or unconsciously, the United States has had a definite and effective policy regarding the increase of population almost from the very beginning of white settlement. The early policy was that of the "open door" which permitted easy entry and encouraged rapid population growth. This policy was gradually shifted until at the present time it appears to be one of population restriction on the part of both individuals and the government. The personal advantages which childlessness, or near childlessness, offer in our industrial civilization restricts the birth rate, while the government restricts the influx from without through immigration regulations. The authors reason convincingly that if this policy is prolonged the birth rate will continue to decline and the future population will tend to be much nearer the above minimum estimate than the maximum.

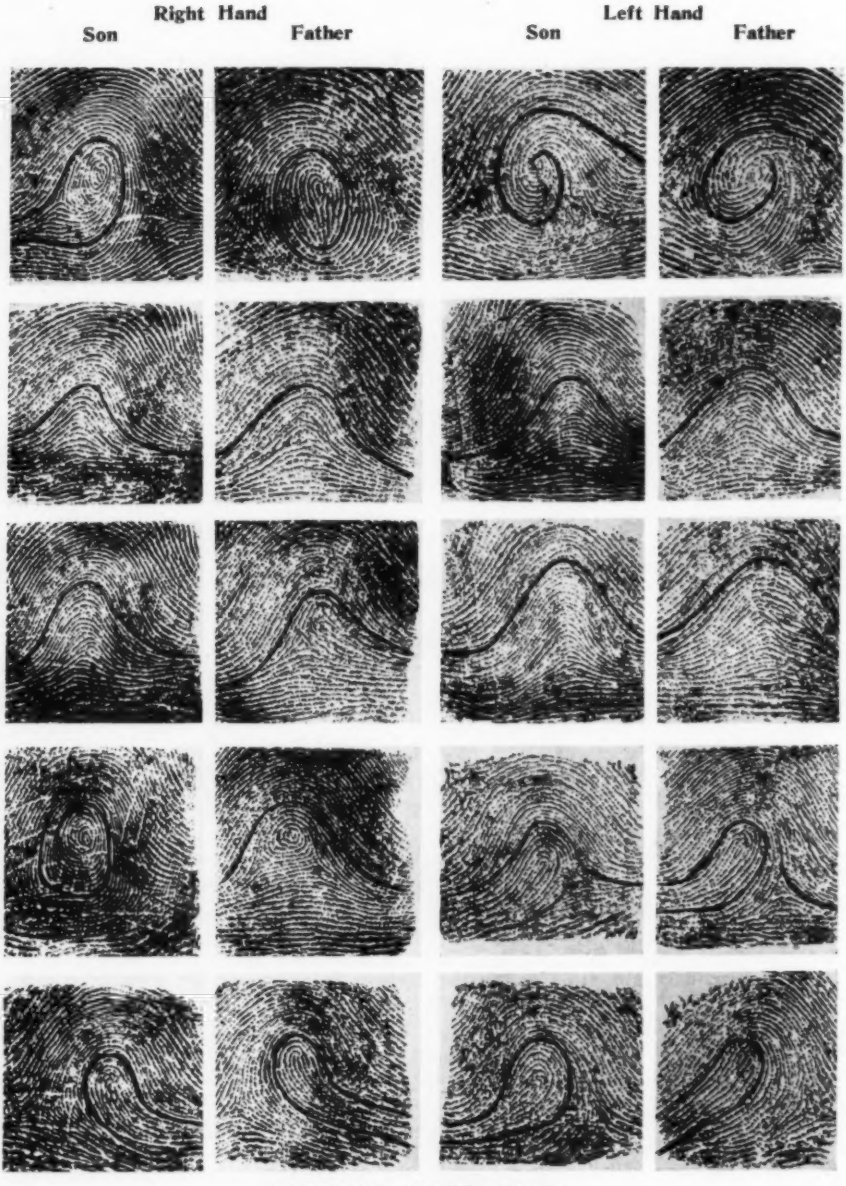
The volume gives a more comprehensive analysis of the population of the United States than any other book at the present time and is a valuable reference work especially for those interested in problems and movements of population.

N. L. Whetten.
Storrs Experiment Station.

Human Genetics in the Medical Curriculum

IN connection with the need for more human genetics in the medical curriculum, stressed by Dr. Macklin in a recent article in the Journal, the following excerpt is of interest:

Frick, federal minister of the interior, has stated that arrangements must be made to give adequate attention to the science of hereditary health, in all grades of public instruction. The state commissar for the Bavarian public health service has approved the introduction of eugenics as a required examination subject in the medical curriculum. Professor Lenz of Munich, an authority on race hygiene, has given his views on the proposed plan in the *Münchener medizinische Wochenschrift*. He insits that race hygiene should be an independent main subject for study. It is not enough to make it a part of the required lectures on hygiene. He recommends that new special chairs for race hygiene be established. A course of lectures on genetics should be added to the preclinical studies as a required subject. For the clinical period, two new four-hour courses of lectures should be made obligatory: (1) hereditary transmission in man and (2) sociological and biological bases of race hygiene. As the introduction of an entirely new main subject appears impossible without changing the remainder of the curriculum, Lenz suggests a lengthening of the semesters. He thinks the short summer semester should be replaced by a full-length fall semester extending from September to December, and for the winter semester a spring semester extending from February to May should be substituted. In addition, he proposed the organization of a two-hour course on methods of human hereditary research in the winter, and a two-hour "colloquium" in the summer, for persons having a special interest in the subject. The directors of the Verband deutscher Medizinerschaften (league of medical students' associations) emphasize that, if such courses are to be introduced, it presupposes a far-reaching reorganization of the medical curriculum, in order to preserve the standards of medical education in general.—"Berlin Letter," *Jour. Amer. Med. Assoc.*, July 17, 1933 (Vol. 101, No. 9).



NOT TWIN FINGERPRINTS

Figure 14

The value of any criterion of twin identity depends on the degree of certainty that as great similarity in a given character would not be found in twins that are non-identical. These fingerprints, of a father and son, show similarities that exceed the degree of similarity found in some identical twin pairs.

GENETIC STUDIES OF MONOZYGOTIC TWINS

II. Finger-patterns and Eye-color as Criteria of Monozygosity*

D. Cecil Rife

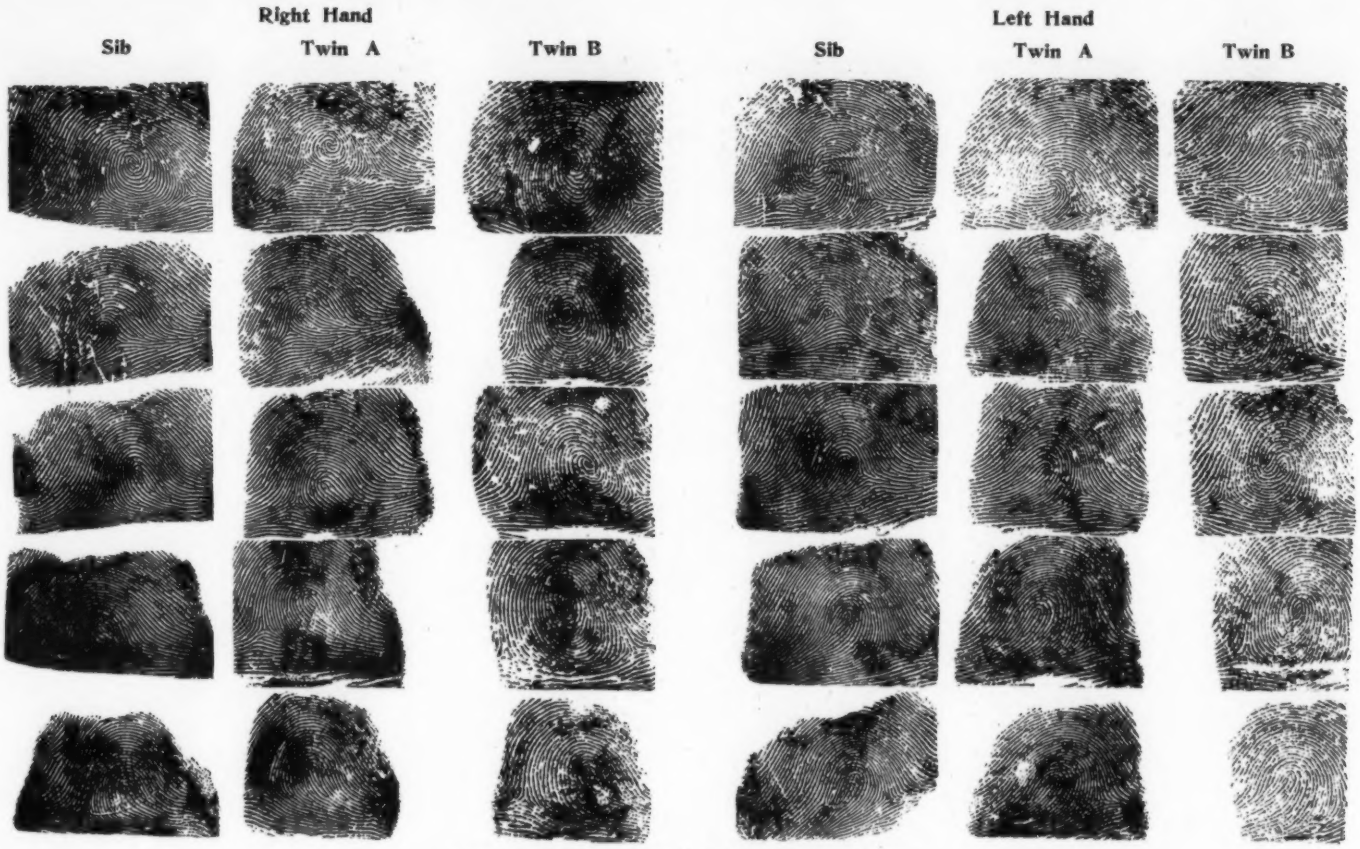
In attempting to determine whether or not a given pair of twins is monozygotic, it may, in many instances, because of lack of facilities, be impracticable to employ all of the tests included in our diagnostic formula.[4] It is highly desirable that some simpler means be devised which can be used, with a fair degree of accuracy.

Finger-pattern comparisons have probably been used for this purpose more frequently than any other single measure. The fact that no two individuals have identical finger-patterns, and that identical twins often show striking intra-pair similarities in this respect, would seem to justify their use. Kaomi[1] and Newman[2,3] state that usually the patterns of the two right hands, and of the two left hands of a pair of identical twins are more similar than the right and the left of either member, and that occasionally mirror-imaging is found, i. e., the patterns of the right hand of one twin are similar to those on the left hand of his mate. Such resemblances, they believe, constitute rather conclusive proof of monozygosity.

In our studies of twenty pairs of identical twins, we have, in each case, made careful intra-pair comparisons of finger-patterns, both for ridge-count values and pattern types. The intra-pair differences of one hundred sib pairs were compared with those of the twins. The patterns were classified as arches, whorls, and ulnar or radial loops, and Bonnevie's method was used in computing the ridge count values. According to this classification the quantitative value of a digit may range from 0 to 10, depending upon the number of ridges between the core and delta or deltas of the pattern. As an arch has no core or delta, it is always assigned a value of 0. That of a loop ranges from 1 to 5, depending upon the number of ridges, those having more than 20 being assigned a value of 5. A whorl, which always has two deltas, may have a value as high as 10, if more than 20 ridges exist between the core and each delta. The total ridge count value, then, of an individual ranges from 0 to 100. In a study of the quantitative ridge count values of 170 individuals, selected at random, Bonnevie found that the distribution was fairly normal, with only a few individuals at each of the extremes. Within families, however, the variations average less, some families having consistently high, and others consistently low values. There is some indication that the quantitative values are largely determined by multiple factors, and that the higher value patterns are dominant to the lower values.

An analysis of our data reveals some interesting and rather surprising facts. The mean intra-pair sib difference in quantitative values was 14.92 ± 1.11, while that obtained for the twins was 4.0 ± 0.88. The greatest identical twin intra-pair difference was 8, while the greatest sib difference was 51. In four cases, no intra-pair twin quantitative differences were found, but, also, in two sib pairs, no quantitative differences

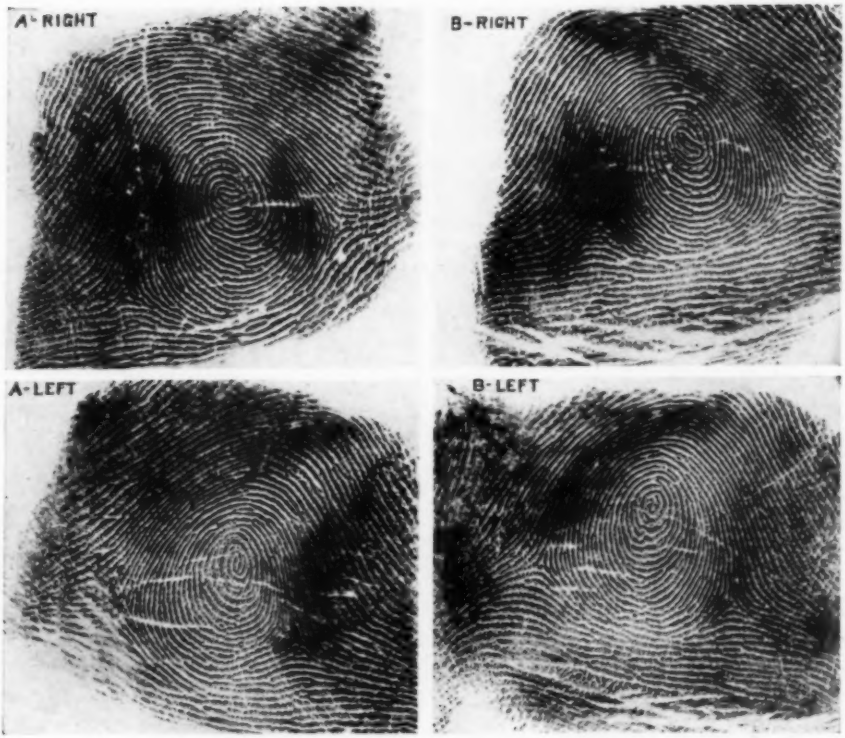
*Prepared in the genetics laboratory of the Ohio State University, under the supervision of Prof. L. H. Snyder. Acknowledgment is also due Miss Josephine Olmstead for assistance in the study of iris pigmentation.



PATTERNS OF TWINS AND SIB DIFFERENT

Figure 15

For comparison with a case showing much closer similarities see Figures 17 and 18.



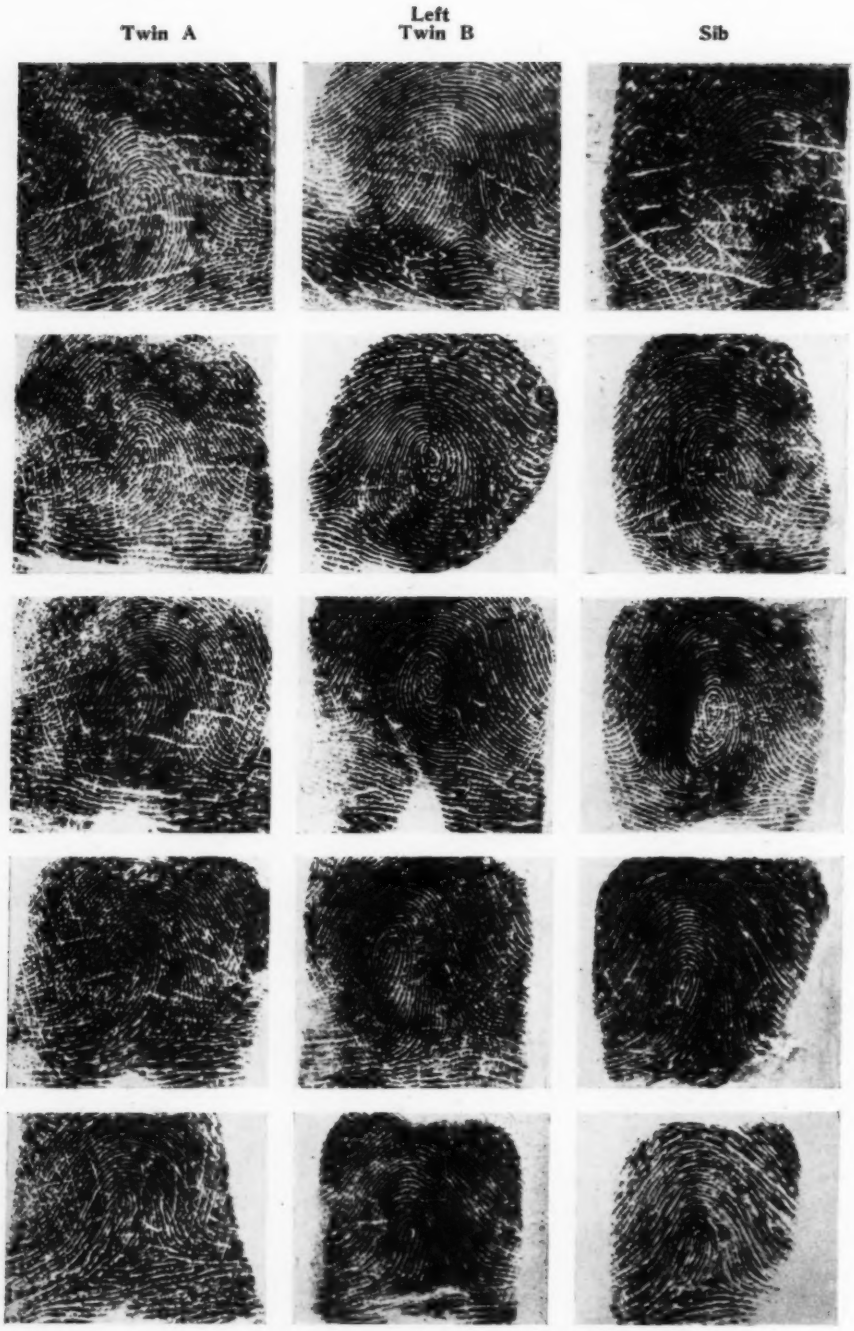
CROSS RESEMBLANCE IN TWIN THUMB-PRINTS

Figure 16

The resemblance between the two right hands and the two left hands is much closer than the resemblance between the respective rights and lefts. Such cross resemblances are convincing evidence that a pair of twins are identical.

were obtained. Although usually intra-pair quantitative differences are greater between sibs than between identical twins, it is by no means a universal rule. Moreover, in a majority of our twin pairs the quantitative similarity between the same sided hands was not greater than between the two hands of the same individual, although it was greater in a few cases.

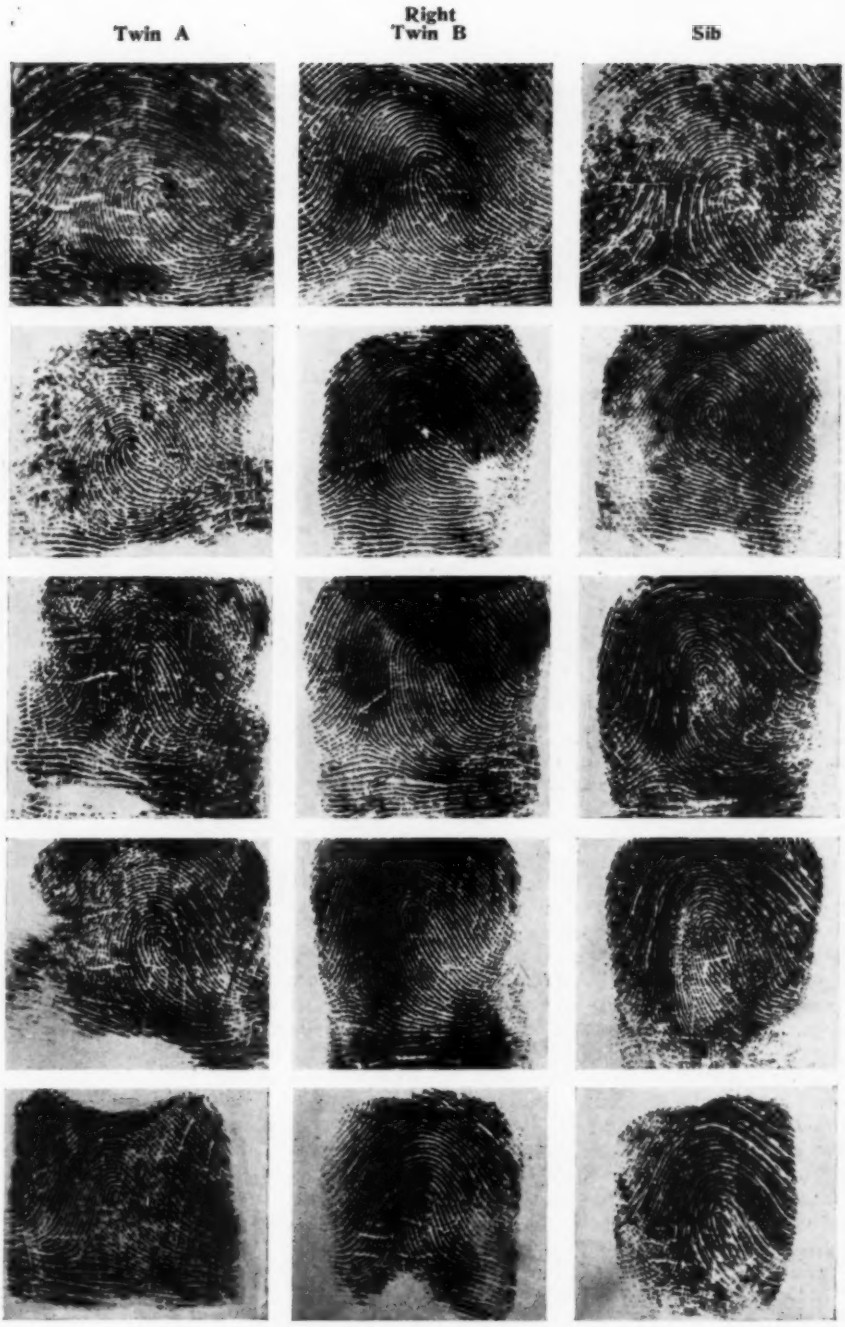
In regard to pattern-types, both sibs and identical twins usually show intra-pair similarities, in respect to kind and distribution, the similarities, as a rule, being greater between twins than between sibs. In some instances, but not the majority, the resemblances were greater between the same sided hands of a twin pair than between the two hands of either individual. Figure 16 shows the thumb prints of a pair of boy twins, a case in which such similarities exist. As noted by Kaomi and Newman, such resemblances are good evidence of monozygosity. No such striking similarities were found in any of the sib pairs, but neither were they found in the majority of identical twins. Not infrequently individuals are found who have ulnar loops on all ten digits; so a correspondence between the members of a twin pair, in this respect alone is little evidence of



SIMILARITIES IN TWIN-SIB FINGERPRINTS

Figure 17

Remarkable correspondences are evident between the patterns of the twins' fingers and those of a sib. Such cases emphasize that taken alone fingerprint patterns may in some cases lead to wrong conclusions with regard to the genetic identity of a pair of twins.



FINGERPRINTS OF THE RIGHT HANDS
Figure 18

While the resemblance between some of the fingers is striking, that between other fingers is not so great.

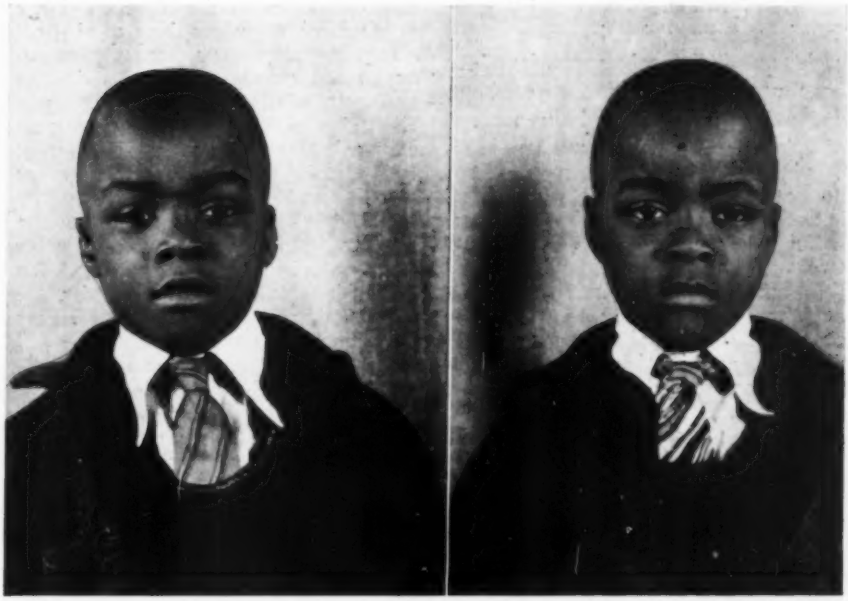
ALIKE IN FINGERPRINT PATTERNS AND IN COLORBLINDNESS
Figure 19

According to our diagnostic formula, the chances are 63,991 in 64,000 that these young men are monozygotic twins. The finger patterns of each consist solely of loops, and the total ridge count value of each is 38. The Ishahara tests show that both are red-green color-blind.

monozygosity. We have obtained the finger-prints of three sisters, two of whom are identical twins, and the finger-patterns of all three individuals are composed solely of ulnar loops. Striking familial resemblances are sometimes found in respect to both ridge count values and pattern types and distribution. Figure 14 shows such a resemblance between father and son, the only difference in pattern type occurring in the middle right hand fingers, the father having a loop of low quantitative value and the son an arch. Considering that arches, loops and whorls are all present, such a resemblance is striking, and would be so, even for identical twins. There is a difference in ridge count values of only two.

Figures 17 and 18 show the finger-prints of a pair of identical twins and a sib. Judging from finger-patterns alone, it would be difficult to determine which two are twins. Yet, according to our diagnostic tests, there are only three chances in 320,000 that the twins are not monozygotic. Figure 15 shows the finger-prints of another pair of identical twins and a sib. In this case there can be little doubt as to which two are twins, there being striking similarities in both pattern types and ridge count values of the twins while the sib shows considerable differences in both pattern types and ridge count values.

In only one of the twenty pairs of identical twins was any evidence of "mirror-imaging" of finger-patterns encountered, and this was for the ring fingers only. A whorl was found on the right ring finger of one twin and on the left ring finger of her



IDENTICAL TWINS—BUT WITH DIFFERENT FINGER PATTERNS

Figure 20

The odds are 4,999 to 1, our tests have shown, in favor of these boys being monozygotic. Yet their finger-patterns are more dissimilar than those of some of our sib pairs. We could detect no difference in shade of skin color. Although their hair had recently been clipped, the direction of head hair whorl was easier to determine than in any of the other nineteen pairs of twins studied.

mate, while an ulnar loop was found on her left ring finger, and on the right of her mate. Even this may have been simply due to chance, rather than to true "mirror-imaging."

These data seem to indicate that the value of finger-patterns for determining monozygosity has been considerably exaggerated, although, when used with other criteria, they are often good indicators. Finger-patterns of identical twins, as a group, are more similar than those of sib pairs, but in many instances the intra-pair differences of identical twins are greater than those of some sib pairs. Intra-pair mirror-imaging of finger-patterns is of such rare occurrence as to be of little value in twin diagnosis.

Iris Differences

In our investigations, we have made intra-pair comparisons of fifty sib pairs, and fifteen identical twin pairs, in respect to iris pigmentation. The eyes were studied by means of the Beebe Binocular Loupe, which gives a magnification of approximately two diameters. All observations were made in bright daylight the members of a pair being examined together. The distribution and hue and chroma values of the pigmentations were mapped for each pair, the Munsell color chart being used in estimating the hue and chroma values.

In the majority of cases studied, the iris was found to be composed of an inner and an outer zone, of dif-

ferent coloration. The zonal boundary is usually quite irregular. Occasionally individuals were found to have uniform coloration throughout, and a few cases showed three zones of coloration. Aside from rare flecks of pigment, 1 or 2 mm. in diameter, no noticeable differences were found between the right and left eyes of an individual. In the fifty sib pairs, no two individuals were found to have the same iris pigmentation throughout the entire iris. In ten cases the outer zones were alike and the inner different, and in six cases the inner zones were alike and the outer different. In fifteen pairs of identical twins the pigmentation and its distribution showed as great similarity as observed between the right and left eyes of a single individual. Judging from these observations, iris pigmentation alone would be sufficient to prove or disprove monozygosity. However, it is a well known fact that the right and left eye of an occasional individual are of quite different coloration, probably due to a somatic mutation. Consequently, we should expect to find an occasional pair of identical twins in which an intra-pair difference in pigmentation exists. Our studies indicate that pure blue-eyed individuals are quite rare, a large number of so-called blue-eyed persons possessing some brown pigment, or an inner gray area. We do not know to what extent iris pigmentation changes with age. Intra-pair comparisons of five pairs of fraternal twins indicate that they vary as greatly as do ordinary sibs so the age factor would not seem to detract greatly from the value of eye color as a criterion of monozygosity. To be valid, tests should be made by one individual, as color perception is not the same in all persons.

Comparisons of eye color are necessarily more indirect than comparison of finger-patterns and physical measurements. However, in comparing the eye color of individuals, it is not necessary to know the absolute hue and chroma values, in order to determine whether or not significant differences exist. Our findings indicate that similar iris pigmentation is a far more reliable criterion of monozygosity than similar finger-patterns, or other physical measurements which have been suggested. Furthermore, considerable technical knowledge is required for an intelligent interpretation of finger-patterns, whereas comparisons of eye color require little or no specialized training.

Literature Cited

1. Kaomi, T., *Quarterly Review of Biology*, 1928, 408-418.
2. Newman, H. H., *Biological Bulletin*, 1928, 298-315.
3. ———— *Biological Bulletin*, 1928, 283-297.
4. Rife, D. C., *Jour. Hered.* 24:339-345.

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A Glossary Of Genetic Terms

GENETICS has developed so rapidly that many terms in common use in genetic literature are not yet incorporated in the dictionaries. Many people who are interested in heredity are bothered by such words, for which no definition can conveniently be found. For this reason, it is proposed to publish occasionally a glossary of terms which would not be readily understood and which are not to be found except in new unabridged dictionaries. It is realized that these definitions will probably not meet with universal approval and comments and suggestions will be welcomed.

ALLELOMORPH—Mendelian characters are inherited in alternative pairs, or in alternative series. These alternative genes are called allelomorphs. Examples: Albinism (recessive), Normal pigmentation (dominant); Horns (recessive), Hornlessness (dominant).

CHROMATID—Chromosomes frequently bear the foreshadowing of a future longitudinal division so that they appear to be made up of two parallel threads. These threads are the chromatids.

CHROMOSOMES—Tiny dark-staining bodies visible in the nucleus of the cell at the time of cell-division. The number of chromosomes in any species is usually constant. The chromosomes carry the genes, linearly arranged, which control the development of Mendelian characters.

CROSSING OVER—Interchange of segments between two homologous chromosomes previous to the formation of gametes.

DIZYGOTIC—Originating from two fertilized eggs. Dizygotic twins are genetically no more similar than ordinary brothers and sisters.

DOMINANT—A character possessed by one of the parents of a hybrid, which appears in the hybrid to the exclusion of the contrasted character from the other parent (the recessive). Thus in a cross of green- and yellow-seeded peas the first generation has yellow seeds. Yellow is dominant and green is recessive, being transmitted but not appearing in the presence of the factor for yellow.

FACTOR—Same as *Gene*.

F_1—(Pronounced eff-one). The first filial generation. The offspring of a given mating.

F_2—The second filial generation. Produced by intercrossing or self-fertilizing the F_1. The inbred grandchildren of a given mating.

GAMETE—A reproductive cell of either sex; e. g. sperm or ovum.

GENE—(1) The unit of inheritance, which is transmitted in the germ cells, and which by interaction with the genic and cytoplasmic complex controls the development of a character. The genes are arranged linearly in the chromosomes. (2) "The physical basis of heredity"—or more figuratively, the atom of the genetic molecule.

HETEROZYGOUS—Containing both genes of an allelomorphic pair, or two genes of an allelomorphic series. Heterozygous individuals generally resemble the individuals homozygous for the dominant character, but they transmit the recessive to half their offspring.

HOMOZYGOUS—(1) An organism formed by like germ cells; (2) An organism is said to be homozygous for a given character when all the germ cells transmit identical genes for this character. This is the most frequently used meaning of the term.

LINKAGE—Association of genes in inheritance, due to the fact that they are in the same chromosome.

MEIOSIS—The reduction divisions preceding the formation of gametes, in which the chromosome pairs separate, and the chromosome number is reduced to half the somatic number.

MONOZYGOTIC—Originating from a single fertilized egg cell, which in the course of subsequent development has given rise (by fission) to two or more individuals. Twins (or triplets, etc.) of such origin are, barring mutations, genetically identical.

MULTIPLE FACTORS—In the expression of some characters more than two genes are necessary. Such cumulative or cooperative genes are called multiple factors.

MUTATION—A sudden variation in an inherited character.

ONTOGENY—The developmental history of an organism, from fertilized egg to adult individual

RECESSIVE—See *Dominant*.

SEGREGATION—Separation of allelomorphic genes at meiosis.

SELFED—Self-pollinated.

SOMATIC—Referring to body tissues; having two sets of chromosomes, one set normally coming from the female parent and one from the male; as contrasted with germ cells having a single set of chromosomes.

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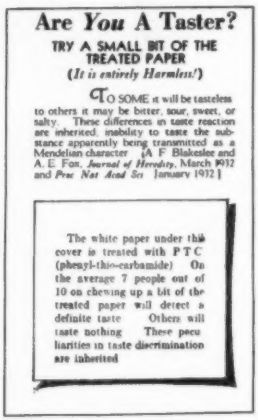
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